UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE BIOLOGIA

EDUARDO DELGADO BRITEZ RIGACCI

THE RESILIENT FRUGIVOROUS FAUNA OF A DEGRADED FOREST FRAGMENT AND ITS POTENTIAL ROLE IN THE ENRICHMENT OF VEGETATION

A FAUNA FRUGÍVORA RESILIENTE DE UM FRAGMENTO FLORESTAL DEGRADADO E SEU PAPEL NO ENRIQUECIMENTO DA VEGETAÇÃO

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Dissertation presented to the Institute of Biology of the University of Campinas in partial fulfillment of the requirements for the degree of Master in Ecology

Dissertação apresentada ao Instituto de Biologia da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do Título de Mestre em Ecologia

ESTE ARQUIVO DIGITAL CORRESPONDE À VERSÃO FINAL DA DISSERTAÇÃO DEFENDIDA POR EDUARDO DELGADO BRITEZ RIGACCI E ORIENTADO PELO PROF. DR. WESLEY RODRIGUES SILVA

Orientador: Dr.Wesley Rodrigues Silva

CAMPINAS

2019

Ficha catalográfica
Universidade Estadual de Campinas
Biblioteca do Instituto de Biologia
Mara Janaina de Oliveira - CRB 8/6972

R448r

Rigacci, Eduardo Delgado Britez, 1993-
The resilient frugivorous fauna of a degraded forest fragment and its potential role in the enrichment of vegetation / Eduardo Delgado Britez Rigacci. – Campinas, SP : [s.n.], 2019.

Orientador: Wesley Rodrigues Silva.
Dissertação (mestrado) – Universidade Estadual de Campinas, Instituto de Biologia.

1. Animais – Extinção. 2. Sementes – Dispersão. 3. Comedouros. I. Silva, Wesley Rodrigues, 1955-. II. Universidade Estadual de Campinas. Instituto de Biologia. III. Título.

Informações para Biblioteca Digital

Título em outro idioma: A fauna frugívora resiliente de fragmento florestal degradado e seu papel no enriquecimento da vegetação
Palavras-chave em inglês:
Animais – Extinção
Seeds – Dispersal
Animal feeders
Área de concentração: Ecologia
Titulação: Mestre em Ecologia
Banca examinadora:
Wesley Rodrigues Silva [Orientador]
Maíra de Campos Gorgulho Padgurschi
Thiago Vernaschi Vieira da Costa
Data de defesa: 29-07-2019
Programa de Pós-Graduação: Ecologia

Identificação e informações acadêmicas do(a) aluno(a)
- ORCID do autor: https://orcid.org/0000-0003-0230-2777
- Curriculo Lattes do autor: http://lattes.cnpq.br/3302344291862586

Campinas, 29 de julho de 2019

COMISSÃO EXAMINADORA

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Prof. Dr. Thiago Vernaschi Vieira da Costa

Os membros da Comissão Examinadora acima assinaram a Ata de Defesa, que se encontra no processo de vida acadêmica do aluno.

AGRADECIMENTOS

Agradeço incialmente à minha família pelo apoio desde sempre, vocês foram meus pilares e essenciais para que esta dissertação se tornasse realidade. Ao Professor Wesley, que desde a iniciação científica acreditou em mim e me deu a oportunidade de integrar seu laboratório, além de ser alguém extremamente prestativo e disposto a passar todo seu conhecimento aos seus alunos. Aos Professores Dra. Eleonore Setz e Dr. Martin Pareja, que compuseram o comitê de acompanhamento, auxiliando no direcionamento e contribuindo enormemente na presente pesquisa e no meu crescimento como cientista. Aos Professores Dra Maíra Padgurschi, Dr. Thiago Vernaschi e Dra. Erika Hasui pelo pronto aceite para compor a pré banca e os dois primeiros pela participação também na pré banca.

Sou grato a todos os meus amigos, da graduação, pós e os que não-biólogos que foram também essenciais na elaboração direta ou indiretamente desta dissertação. Em especial meus amigos e companheiros de LIVEP, Nathi, Zé, Ana, Cris, Diego, Chris, Ida, Jasmin, Nathi, Mari, Elisa, Renato e Jana.

Por fim, reitero meu agradecimento ao Instituto de Biologia da UNICAMP, ao PPG-Ecologia e a todos os membros da Mata Santa Genebra, que durante os meses de campo tão bem me acolheram e ofereceram todo suporte necessário. Também ao CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico, processo Nº0003-0230-2777), órgão financiador minha pesquisa e milhares de outras no Brasil, mas que atualmente está ameaçado de extinção pela atual gestão do poder executivo.

RESUMO

A perda de diversidade, riqueza e biomassa da fauna, principalmente de mamíferos e aves de médio e grande porte, por atividades antrópicas pode ser denominada como 'defaunação antropocênica'. Tal processo afeta funções ecológicas e, por consequência, serviços ecossistêmicos importantes desempenhados por estes animais, como a dispersão de sementes, colocando em risco ecossistemas e biomas com grandes quantidades de flora lenhosa zoocórica, como a Mata Atlântica, além de prejuízos econômicos diversos. Embora a redundância ecológica, presente em sistemas complexos como as florestas tropicais, possa amortizar as perdas funcionais causadas pela defaunação, são raros os estudos que realizam induções do processo de redundância, com uso de comedouros cevados com frutos, como forma de enriquecer e recuperar ambientes naturais. Assim, nosso objetivo é avaliar o potencial da fauna residual de frugívoros em um fragmento defaunado de Mata Atlântica de formação semidecídua para o enriquecimento com espécies zoocóricas de plantas. Selecionamos 36 pontos amostrais na Mata Santa Genebra, Campinas/SP, e instalamos comedouros em duas alturas diferentes e monitorados por *cameras-trap*. Quantidades variáveis de frutos nativos de espécies zoocóricas foram oferecidos alternadamente nos comedouros. Com base em mais de 36.000 horas de registros, constatou-se que *Turdus leucomelas*, *Sapajus nigritus* e *Salvator merianae* foram as espécies que ingeriram a maior riqueza de frutos. *Didelphis albiventris* foi o visitante mais assíduo, mas na maioria das visitações realizou comportamento de despolpe do fruto, deixando as sementes nos comedouros. Como esperado, maio foi o mês de maior visitação às cevas por ser o mês de menor frutificação das espécies zoocóricas no local de estudo. Para a avifauna frugívora, a disposição de maior quantidade de frutos aumenta também a visitação considerada efetiva, relação inversa encontrada para mamíferos. A explicação se baseia no comportamento esperado para cada táxon em relação ao despolpe dos frutos, mais proeminente em mamíferos frugívoros do que para aves. O componente de paisagem "Matriz de Entorno" afetou de maneira diversa o padrão de visitação dos dispersores de sementes. Mostramos que o aumento da diversidade de frugívoros leva à maior chance de visitas com ingestão de sementes e a explicação é baseada na relação clássica entre biodiversidade e funções ecossistêmicas. Com este estudo mostramos a importância positiva e eficaz do uso de cevas enriquecidas com frutos e seu potencial em atrair frugívoros em um fragmento de Mata Atlântica defaunado, utilizando assim sua função de dispersão de sementes para enriquecimento florístico local. Contudo,

variações nos padrões de visita e ocupação de espaço devem ser levados em conta em futuros planos de manejo.

Palavras-chave: defaunação, redundância ecológica, dispersão de sementes, comedouros artificiais

ABSTRACT

The loss of diversity, richness, and biomass of the fauna, mainly of mammals and birds of medium and large size, by anthropic activities can be denominated as “anthropocentric defaunation” This process affects critical ecosystem services performed by these animals as seed dispersal, putting at risk ecosystems and biomes with large amounts of zoochorous flora such as the Brazilian Atlantic Rain Forest. Although the ecological redundancy present in complex systems such as rainforest can amortize the functional losses caused by defaunation, studies that perform inductions of the redundancy process with the use of fruit-fed feeders as a way of enriching and recovering natural environments are rare. Thus, our objective in the present study was to evaluate the residual fauna with potential for the enrichment of a Semideciduous Seasonal Forest fragment with native plant species. A total of 36 sampling points was selected at Mata Santa Genebra, with two feeders installed at different heights that were monitored by camera-traps. Variable amounts of native fruits of zoochorous species were offered alternately in the feeders. Based on more than 36,000 hours records, *Turdus leucomelas*, *Sapajus nigritus*, and *Salvator merianae* were the species that ingested the highest fruit richness. *Didelphis albiventris* was the most frequent visitor but depulped most of the fruits, leaving the seeds in the feeders. As expected, May was the month with most significant visitation to the feeders, due to the lowest fruit production of the zoochorous species at the study site. In relation to the frugivorous avifauna, the disposal of a larger quantity of fruits increases the visitation considered "effective," but the inverse relationship was found for mammals. The explanation is related to the behavior expected for each taxon concerning fruit depulp, more prominent in frugivorous mammals than for frugivorous birds. The landscape component "Environment Matrix" affected the pattern of visitation of seed dispersers differently. We showed that an increase in the diversity of frugivores leads to a higher chance of effective visitation, and the explanation is based on the classic relationship between biodiversity and ecosystem functions. Finally, with this study we can highlight the decisive and efficient importance of the use of fruit-enriched feeders and their potential to attract resilient frugivores in a defaunated Atlantic Rain Forest fragment, by using their seed dispersal services for local floristic enrichment. However, variations in the patterns of visitation and occupation of space should be taken into account in future management plans.

Key-words: defaunation, ecology redundancy, seed dispersal, artificial fruit feeders.

Abbreviation list

AFF: Artificial Fruit Feeders;

FAF: Fruit Availability Index

FCV: Fruit consuming visit;

GLMM: General Linear Mixed Models;

ICC: Interclass Correlation Class;

ISD: Induced Seed Dispersion

MSG: Mata Santa Genebra;

NCV: Non-consuming visit;

NFV: Non-fruiting visit;

PMV: Pulp Mashing Visit;

SIP: Seed Ingestion Probability;

SUP: Space Use Patterns;

VIF: Variance Inflation fator

SUMMARY

1.0 Introduction

Seed dispersal, an ecosystem process performed by frugivorous species, is of great importance for the ecosystem functioning and maintenance (Tewksbury *et al*., 2002). Such interaction has innumerous benefits to plants, contributing to gene flux increase (Carvalho *et al*., 2016; Godoy & Jordano, 2001), seed predation decrease (Galleti *et al*., 2006) and establishment in favorable sites, free from density mortality and distant from enemies, such as pathogens and seed predators, directly affecting species fitness (Wang & Smith, 2002).

Animals are categorized as frugivorous if they consume, at least seasonally, in part of their diet fruits with seeds, maintaining theses seeds viable after regurgitated or defecated (Fleming *et al*., 1987; Galetti & Aleixo, 1998; Raupp *et al*., 2009). Socioeconomically, the direct importance of zoochory has been pointed out as in regard to commercially exploited plants that represent a millionaire market in Brazil, such as the Açai Palm (*Euterpe oleracea*) and Brazil Nut (*Bertholletia excelsa*), which depend on animal dispersion of seeds for their conservation (Baider, 2000).

Notwithstanding, a rapid expansion of anthropic activities such as agriculture, expansion of urban and industrial boundaries, has led to accelerated degradation of natural areas, reducing them to fragmented communities (Tabarelli & Gascon, 2005). This process has led to the loss of diversity, richness, and biomass of the fauna, mainly of mammals and birds of medium and large size, in a process called 'anthropocentric defaunation' (Redford, 1992; Wright *et al*., 2007; Dirzo, *et al*., 2014; Young *et al*., 2016).

Defaunation results in a scenario of genetic and ecological implications that may lead to the entire extinction of flora populations through inbreeding depression, and loss of propagules vectors and pollinators (Tewksbury *et al*., 2002). This scenario is intensified in Neotropical communities, since 75% of plant species in these localities are zoochorous (Galindo-Gonzales *et al*., 2000).

In 1992, Redford coined the term "empty forest syndrome," which refers mainly to tropical forests that are not totally degraded in terms of flora, but, due to fragmentation processes and other anthropic pressures, such as extractive activities of wood, have lost much of their medium and large-sized faunae – jeopardizing key mutual relationships such as seed dispersal. These relationships were crucial for the establishment and structural configuration of these biomes in past times, and now their absence risks the permanence and maintenance of these communities on a space-time scale (Wilkie *et al*., 2011; Galetti, et al., 2016)). In many systems, the absence of frugivores altered the floristic composition, benefiting plant species

with abiotic dispersion (Wright *et al*. 2001, Cordeiro & Howe 2003; Vanthomme *et al*., 2010). This reduction of zoochoric plants generates positive feedback between frugivores and plant communities; the alteration in seed dispersal patterns influences the ecosystem capacity for maintaining plants as well as animal populations, through loss of secondary process such as fertilization (Figure 1) (Terborgh, 2012; Terborgh, 2013; McConkey et al., 2011; Terborgh *et al*., 2008; Tabarelli *et al*., 2004).

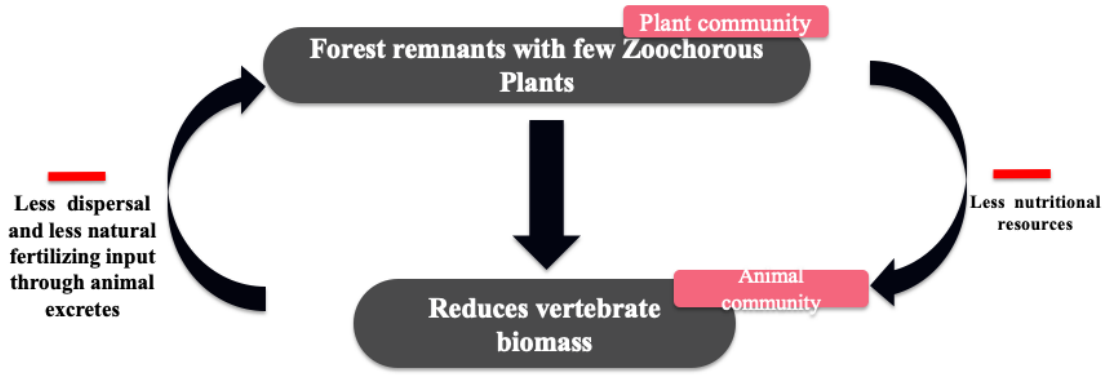

Figure 1: Forests with a reduced number of zoochoric plants offer fewer resources to vertebrates, which in turn have their biomass reduced, affecting the quantity and quality of seed dispersal, as well as the fertilization of the soil through urine and feces, which reverberates back into plant communities, decreasing rates of establishment of new adults.

Cordeiro & Howe (2003) observed that frugivorous birds were rare or absent in small plots of fragments of forest in Tanzania. Consequently, the visitation of the fruits of an endemic tree species, *Leptonychia usambarensis*, was locally smaller, as well as the establishment of the seedlings in the adjacencies, which may also compromise the food source for the local frugivores. There are indications that the defaunation of tropical forests remnants in northeastern Brazil might lead to the extinction of 33% of the Atlantic Forest trees in the medium and long term (da Silva & Tabarelli, 2000).

One example is the depletion of the *Euterpe edulis* populations, a keystone palm native to Brazilian Atlantic Forest, caused in part by the absence of reliable seed dispersers (Galetti *et al*., 2013). There are also indications of significant evolutionary changes in the flora, such as a decrease in seed size along a defaunation gradient, which may represent essential losses in the establishment and germination (Galetti *et al*., 2013). It is expected that small fruits will be favored by defaunation because plant species that have a large fruit size could only be dispersed by few specialized dispersers with a large gape (Cordeiro *et a*l., 2009).

In some areas, however, faunal species may persist due to their wide niche width, and provide redundancy of some ecological functions of already absent species on forest fragment, i.e., different species performing the same function (Loreau, 2004; Frost *et al*., 1995, Jordano *et al*., 2007; Emer *et al*., 2018). From the standpoint of plant fitness, ecologically redundant dispersers are those that perform proportionally similar seed removal, provide similar treatment that promotes dormancy breaking, and disperse them in similar environments, far from co-specific ones (Loiselle *et al*., 2007). This natural process increases the resilience of ecosystems and constitutes a possible mechanism to be exploited for the conservation of biological diversity (Walker, 1995).

The reversal of floristic impoverishment processes becomes important in depleted tropical formations such as the Atlantic Forest and the Brazilian Savana called Cerrado. Both are considered biodiversity hotspots by The Conservation International (CI) and have only small percentages remaining of their original formations (Joly, *et al*., 2014; Belo *et al*., 2017; Ribeiro *et al*., 2009). Some of their habitats are being compressed into urban fragments, such as Tijuca Forest (Rio de Janeiro/RJ) and Mata Santa Genebra (Campinas / SP), which places them in a continuous risk of extinction due to increased risk of germination failures of new propagules, since there is absence of the seed dispersal service (Galindo-Leal, C., & Câmara et al., 2005; Tabarelli & Gascon, 2004).

Thus, the restoration of such key mutual relationships becomes essential. The lack of frugivores for long periods can lead to alternative states that resemble the original formations in form, but not in function, offering medium and long-term risks to other services rendered by the flora and which are essential to the well-being of anthropic communities, such as air purification, springs and climate regulation (Brodie & Aslan, 2012; Harrison et al., 2013, Malhi et al., 2014, Chazdon , 2014; Marques & Burslem, 2015).

The reintroduction or the increase of plant population groups that have become rare, threatened and at risk of local extirpation, for example, early successional species by direct sowing, are both related to the reversal of flora depletion in many tropical research works (Brancalion *et al*., 2013). A process than can be, sometimes, costly and less effective than natural regeneration (Crouzeilles, *et al*., 2017). Therefore, in this study, we proposed the use of fruit feeders as a tool. Feeders, in special bird feeders, have been widespread in a temperate zone and represent an essential allochthonous resource to generalist fauna, which is prone to explore these novel resources, in particular during winter, when some resources became

unavailable, and so, feeders could represent an important food source (Robb *et al*., 2008; Møller, 2009; Fuller *et al*., 2013; Tryjanowski *et al*., 2015).

Although some studies point to the phenomenon of ecological redundancy in specific zoochorous processes in several ecosystems under different conservation status (Rother *et al*., 2015 Bueno *et al*., 2013, Polak *et al*., 2014, Menke *et al*. 2012; Alves-Costa & Eterovick, 2007), there are no published studies that attempt to evaluate the potential of the residual fauna in communities of 'empty forests' under the stimulus of the extra supply of fruits. In order to use the function of the remaining frugivores for a process of local restoration by enrichment with native zoochorous plants, in the present study we hypothesized that: a) In the absence of more specialized frugivores, the residual frugivorous fauna could be used as an enrichment tool in a defaunated forest fragment, by dispersing seeds of native zoochorous fruits disposed in artificial fruit feeders; b) Fruit ingestion by frugivores would be affected by fruit traits, i.e., some fruit features may be more attractive to the residual fauna; c) The frugivores visits and patterns of space use will also be influenced to extra-fruit characteristics (e.g., season, Forest conservation status).

2. Objectives

In this context, our general objective was to evaluate the residual fauna with potential for the enrichment of a Semideciduous Seasonal Forest fragment with native plant species.

Our specific objectives were:

- To characterize the composition, the use of space and the temporal variation in fruit consumption of these potential seed dispersers;

- To verify the fruits traits that can be more attractive to use in artificial fruit feeders (AFF herein);

- To verify whether AFF set in the fragment are attractive for the resilient frugivores and increase the dispersal performance spectrum of some frugivores;

- To evaluate the importance of the supplementary fruit supply for the enrichment of the fragment in order to contribute to the management of protected areas (PAs) where the fragment is inserted and in other PAs of this same formation elsewhere.

3. Material and Methods

3.1 Study area

The study was conducted at Mata Santa Genebra (hereafter MSG) (22°44′45″S; 47°06′33″W; 670 m), a federal reserve with 251,77 ha located at Campinas municipality, São Paulo State. MSG is surrounded both by agricultural areas and urban perimeter with activities of high environmental impact, like oil refineries, highways, and industries in general (França *et al.*, 2002). It is an important area of study because it is an isolated fragment of forest that is legally protected (second largest urban forest in Brazil),geographically close to large research centers, such as UNICAMP, and managed by a municipal foundation that develops different programs for the preservation of the local flora and fauna, as well as for the environmental education (Morellato & de Freiras, 1995; Santin,1999) (figure 2).

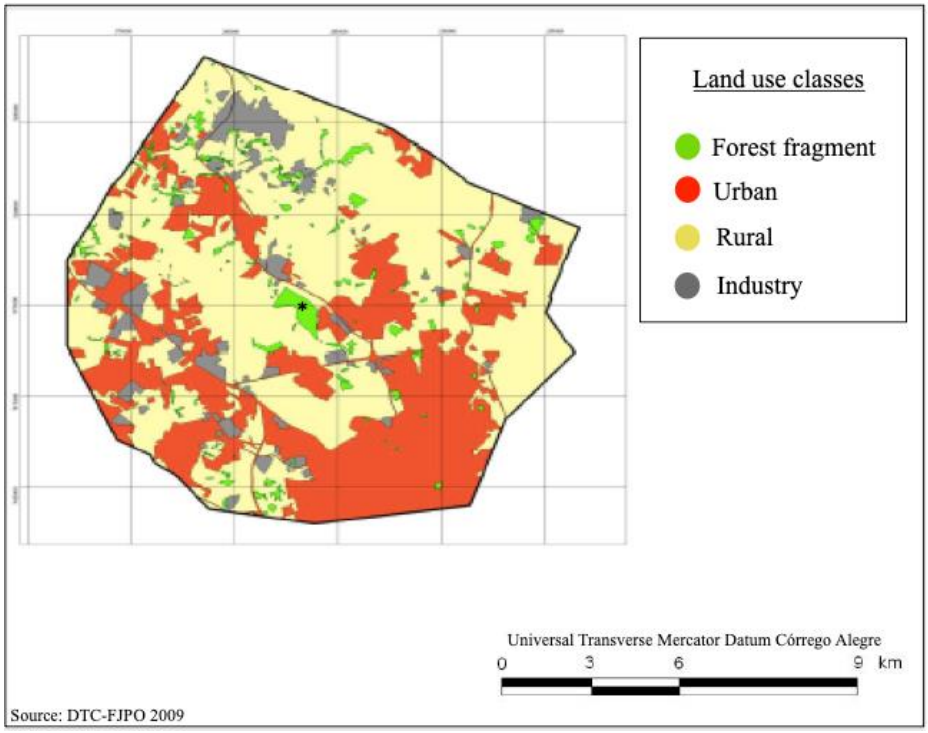

Figure 2: Land-use activities surrounding a 10 km radius of the MSG fragment (marked with *). Map elaborated by DTC-FJPO 2009

This fragment is a remnant of the Seasonal Semideciduous Forest, one of the physiognomies of the Atlantic Forest Domain (Oliveira-Filho e Fontes 2000) in Southeast Brazil, that formerly covered most of the state of São Paulo and is now a priority area for biodiversity conservation due to its exceptionally high species richness and endemism (Martini, et al. 2007). Two main conservation status can be found in the fragment: early and late successional stages (Guaratini *et al.*,2008). The regional climate according to Köeppen

classification is CWA, characterized by a hot and humid season between October and March, with a mean temperature ranging between 22 and 24 ºC with rainfall averages of 1.057 mm, and a dry season, from April to September, with a mean temperature of between 18 and 22ºC, with rainfall averages 35mm (Farah *et al*., 2014).

Previous wildlife surveys indicated the presence of bird species such as the Red-crowned Ant-tanager (*Habia rubica*), and the Blue Manakin (*Chiroxiphia caudata*) (Aleixo & Vielliard, 1995). Among the mammals, the reserve harbors the Black-horned Capuchin (*Sapajus nigritus*), the Brown Howler Monkey (*Alouatta guariba*), the Crab-eating Fox (*Cerdocyon thous*), among other species of marsupials and bats (Paschoal & Galetti, 1995; Morellato & de Freiras, 1995). However, different anthropic pressures over the last decades have led to a constant defaunation processes, resulting in the absence of medium and large frugivores, such as the Lowland Tapir (*Tapirus terrestris*); the Agouti (*Cuniculus paca)*; the Solitary tinamou (*Tinamus solitarius*) and the Red Brocket (*Mazama Americana*) (Galetti & Sazima, 2006). Such local extirpation could cause the decrease of seed dispersion, manly of medium and large fruits, for example, the fruits of *Hymenaea coubaril* (Fabaceae), only dispersed by Green-agouti (*Dasyprocta azarae*) which is currently absent on the fragment (Hallwachs, 1986; Galetti & Sazima, 2006)

3.2 Sampling

Thirty-two sampling stations were randomly set on the MSG fragment (Figure 3), each one consisting of an MDF tray (30 x50 cm) where fruits were supplied and that are referred in this study as Artificial Fruit Feeders (AFF). In half of them, the tray was laid on the soil surface (Figure 4A) and in the remaining the tray was attached to the top of a 180 cm wooden pole (Fig. 4B). All the sampling points were separated by at least 200 m from each other and distributed across successional stages.

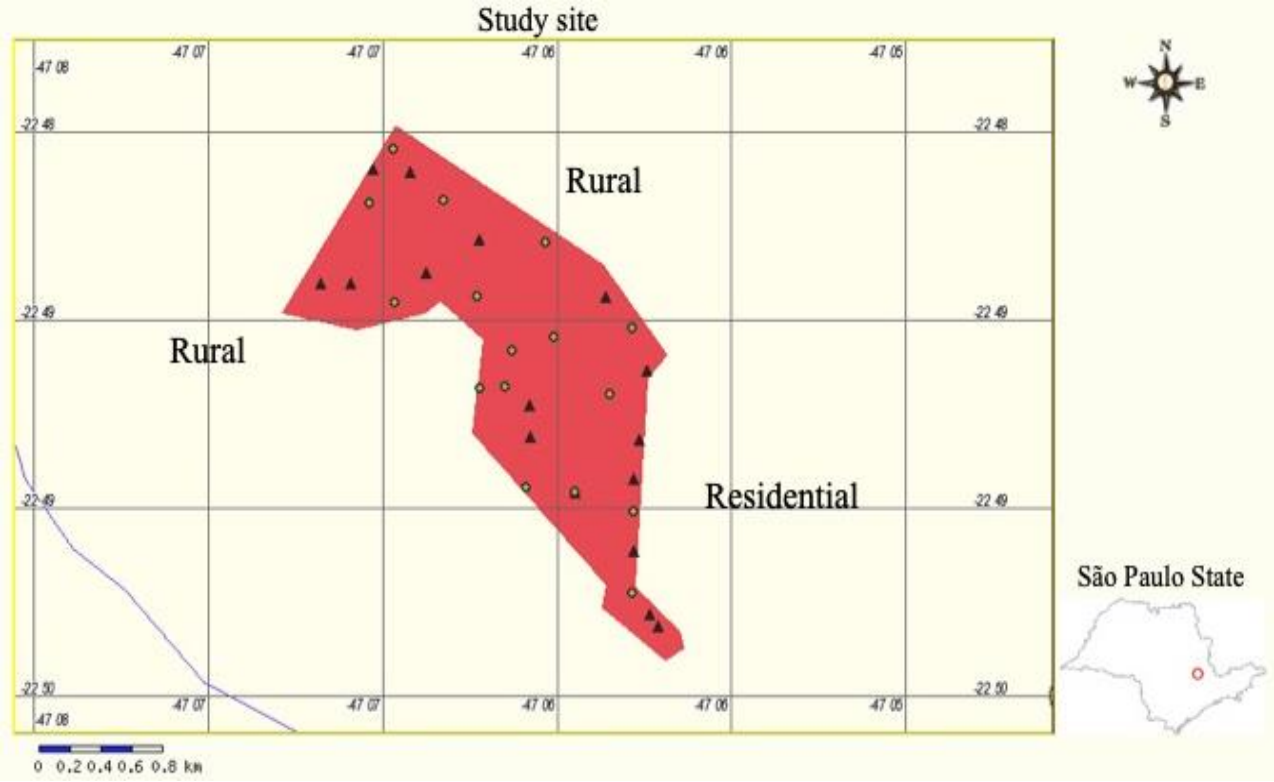

Figure 3 The Mata Santa Genebra fragment, with indications of the Survey Stations. The triangles represent the suspended trays attached to the wooden pole and the circles the trays laid on the ground. The main matrix types are also indicated in the map.

Figure 4: The two types of sampling stations, with the Arificial fruit feeders (AFF) laid on the ground (A) and atop a wooden pole (B). A minimum separation of 200 m between poles assured spatial independence between samples.

The fleshy fruits offered on the trays were all native to the Semideciduous Atlantic Forest and collected from three sites: the green areas of University of Campinas (UNICAMP) (22º49'21.30''S, 47º04'03.82''W), the *Sítio Frutas Raras* in Campina do Monte Alegre (23º 32' 09.08''S, 48º 30'44.62''W), some Atlantic Forest remnants in Vinhedo, São Paulo state (23º 01'11.71''S, 46º56'50.89''W) and in the same forest fragment at MSG (Table 1). Afterwards, all the fruits were screened, and some morphometric measurements were taken (pulp and seed diameter, mass, seed amount) at the Laboratory of Vertebrates-Plants Interactions (Appendix I).

From September 2017 to September 2018 fruits were weekly disposed in 10 out of 32 stations in AFF and a trail camera (Bushnell, model 119436) was attached to the trunk base of an adjacent tree, in a distance suitable to record the frugivores visits (aprox. 1.0 m). Each successive week, the same 10 cameras were rotated to 10 different spots, until all the sampling stations were sampled. In order to avoid food habituation, the same sampling station was never supplied with fruits in subsequent weeks. Food habituation can lead to long-term problems such as obesity (Auman *et al*., 2008); low mobility (Ottoni *et al*., 2009) and low reproductive success (Pierotti and Annet, 1991).

The trail cameras were set to record, after being triggered by any animal movement, for 45 seconds with a 5 seconds interval between shots, in a continuous function and with the

date and time function activated (Paredes *et al.*, 2007). Videos were able to identify the consumer species, count the ingested fruits and seeds, and divide the visits into four different types: Pulp Mashing Visit (PMV), when the animal consumed the pulp wholly or in part but left the seed on the tray; Fruit consuming visit (FCV), when the whole fruit was ingested or removed from the tray with the beak, paws, or mouth, beyond the camera field vision; Non-consuming visit (NCV), when the animal only smelled or manipulated the fruit in the tray without consuming it; Non-fruiting visit (NFV), when the animal visited an empty tray.

Table 1: Fruit offering schedule, specifying the experimental week, month, fruit family, species, number of fruits offered in that week and their provenance.

Week	Month	Fruit Family	Fruit species	Nº Fruits	Fruit provenance
1	September	Myrtaceae	*Eugenia involucrata*	300	Campinas
2	September	Myrtaceae	*Eugenia involucrata*	340	Vinhedo
3	October	Myrtaceae	*Eugenia uniflora*	310	Vinhedo
4	October	Myrtaceae	*Eugenia uniflora*	220	Vinhedo
5	October	Myrtaceae	*Eugenia uniflora*	307	Vinhedo
6	October	Myrtaceae	*Eugenia cauliflora*	300	Campinas
7	November	Myrtaceae	*Eugenia cauliflora*	150	Campinas
8	November	Primulaceae	*Stylogyne depauperata*	120	Sítio F. Raras
	November	Myrtaceae	*Eugenia selloi*	4	Sítio F. Raras
	November	Myrtaceae	*Eugenia brasiliensis*	40	Sítio F. Raras
9	November	Moraceae	*Sorocea bonplandii*	5	Sítio F. Raras
10	November	Moraceae	*Sorocea bonplandii*	5	Sítio F. Raras
11	November	Myrtaceae	*Eugenia brasiliensis*	150	Vinhedo
	November	Primulaceae	*Stylogyne depauperata*	30	Sítio F. Raras
	November	Myrtaceae	*Eugenia brasiliensis*	100	Vinhedo
12	December	Solanaece	*Garcinia gardneriana*	200	Campinas
	December	Myrtaceae	*Eugenia pyriformis*	40	Sítio F. Raras
	December	Myrtaceae	*Eugenia uniflora*	100	Campinas
	December	Myrtaceae	*Eugenia brasiliensis*	150	Campinas
13	December	Myrtaceae	*Eugenia brasiliensis*	150	Campinas
	December	Solanaece	*Garcinia gardneriana*	180	Campinas
14	January	Malphigiaceae	*Malpighia emarginata*	100	Campinas
15	January	Myrtaceae	*Eugenia brasiliensis*	100	Campinas
16	January	Lamiaceae	*Vitex megapotamica*	130	Campinas
17	January	Caricaceae	*Jaracatia spinosa*	5	Campinas
18	February	Myrtaceae	*Psidium myrtoides*	300	Campinas
19	February	Myrtaceae	*Psidium myrtoides*	400	Campinas
20	February	Myrtaceae	*Psidium myrtoides*	400	Campinas
21	March	Myrtaceae	*Psidium myrtoides*	450	Campinas
22	March	Myrtaceae	*Eugenia candolleana*	100	Campinas
23	March	Myrtaceae	*Eugenia candolleana*	60	CCampinas
24	April	Malphigiaceae	*Byirsonima lancifolia*	20	Sítio F. Raras
	April	Myrtaceae	*Psidium vienensis*	20	Sítio F. Raras
	April	Solanaceae	*Solanun diploconos*	15	Sítio F. Raras
	April	Myrtaceae	*Campomanesia sessiliflora*	4	Sítio F. Raras
	April	Melastomataceae	*Leandra australis*	30	Sítio F. Raras
	April	Myrtaceae	*Eugenia candolleana*	30	Campinas
	April	Melastomataceae	*Leandra xanthocoma*	20	Sítio F. Raras
25	April	Myrtaceae	*Eugenia candolleana*	40	Campinas
	April	Myrtaceae	Psidium myrtoides	200	Campinas
26	April	Anacardiaceae	*Schinus terebinthifolius*	400	Campinas
27	April	Anacardiaceae	*Schinus terebinthifolius*	400	Campinas
28	April	Anacardiaceae	*Schinus terebinthifolius*	200	Campinas
29	May	Arecaceae	*Euterpe edulis*	80	Campinas
	May	Anacardiaceae	*Schinus terebinthifolius*	150	Campinas
30	May	Anacardiaceae	*Schinus terebinthifolius*	200	Campinas
31	May	Solanaceae	*Garcinia gardneriana*	400	Campinas
32	May	Myrtaceae	*Campomanesia hirsuta*	5	Sítio F. Raras
	May	Myrtaceae	*Psidium sartorianum*	20	Sítio F. Raras
	May	Rubiaceae	*Guettarda pohliana*	20	Sítio F. Raras
	May	Myrtaceae	*Eugenia punicifolia*	20	Sítio F. Raras
33	June	Calophyllaceae	*Calophyllum brasiliense*	80	Campinas
	June	Solanaceae	*Garcinia gardneriana*	100	Campinas
34	June	Calophyllaceae	*Calophyllum brasiliense*	60	Campinas
	June	Solanaceae	*Garcinia gardneriana*	100	Campinas
35	July	Anacardiaceae	*Schinus terebinthifolius*	300	Campinas
	July	Solanaceae	*Garcinia gardneriana*	200	Campinas
	July	Calophyllaceae	*Calophyllum brasiliense*	80	Campinas

36	July	Solanaceae	*Garcinia gardneriana*	100	Campinas
	July	Anacardiaceae	*Schinus terebinthifolius*	300	Campinas
37	July	Solanaceae	*Garcinia gardneriana*	150	Campinas
	July	Calophyllaceae	*Calophyllum brasiliense*	80	Campinas
38	August	Calophyllaceae	*Calophyllum brasiliense*	90	Campinas
	August	Chrysobalanaceae	*Licania tomentosa*	5	Campinas
	August	Solanaceae	*Garcinia gardneriana*	100	Campinas
39	August	Solanaceae	*Garcinia gardneriana*	173	Campinas
	August	Anacardiaceae	*Schinus terebinthifolius*	300	Campinas
	August	Vitaceae	*Cissus verticillata*	125	Campinas
40	August	Vitaceae	*Cissus verticillata*	130	Campinas
		Calophyllaceae	*Calophyllum brasiliense*	40	Campinas
41	August	Solanaceae	*Garcinia gardneriana*	45	Campinas
	August	Vitaceae	*Cissus verticillata*	100	Campinas
42	September	Vitaceae	*Cissus verticillata*	120	Campinas
	September	Myrtaceae	*Plinia cauliflora*	200	Campinas
43	September	Myrtaceae	*Plinia cauliflora*	300	Campinas
		Vitaceae	*Cissus verticillata*	30	Campinas
44	September	Myrtaceae	*Plinia cauliflora*	120	Campinas
45	September	Solanaceae	*Garcinia gardneriana*	100	Campinas
	September	Vitaceae	*Cissus verticillata*	40	Campinas

As subsequent 45 s video shots separated by 5 s intervals do not represent independent temporal samples, visits by the same frugivore were considered temporally independent only when separated, on the same day and in the same point, by a ≥30 min interval. This procedure reduces the temporal dependency between cameras trap detections (see Paredes et al., 2017).

3.3 Statistical analysis

3.3.1 Exploratory analyses

All the exploratory analyses of the study data and presented on this report through graphs were made using the Package ggplot2 version 3.1.0. (Wickham,2016).

3.3.2 Models of Seed Ingestion Probability (SIP) and Space Use Patterns (SUP)

We chose GLMM (General Linear Mixed Models) to analyze our data because it provides a framework for analysis of non-normal error distribution data and include random effects, which is helpful for understanding how secondary factor influence the outcome, such as space-time influences (Using Package lme4 version 1.1-19) (Bates, *et al*., 2014).To answer the question whether some fruit traits influence their chance to be dispersed away from the study stations and whether that chance varies according to animal vectors, GLMM was used with a binomial error distribution and a *logit* link function, taken fruit attributes (fruit and seed diameter; seed, pulp and fruit mass; seed quantity per fruit; Fruit abundance on AFF) as fixed factors and space and time features (matrix, family fruit, month and year station) as random factors, and the binary response variable for each frugivore (ingested=1, not-ingested=0). This model was referred as SIP in our study.

To determine which mechanisms, explain the pattern of space use by frugivores it was performed a GLMM with a Poisson error distribution and a log link function. Study site variables (Sampling Stations Height, Conservation Status) and Matrix Types are taken as fixed factors and fruit (family and species), visitation (month) as random factors (Table 2). The species' visitation abundance was the response variable. Initially, for this model selection, the visits were divided among taxa and, then, intra-taxa variations were explored. Not only the FCV was considered, but also NFV, NCV and PMV visitors, which can be also potential frugivores as described in the literature. This model was referred as SUP in our study.

Table 2: Some variables and their Categories used on the SIP and SUP models

VARIABLE	CATEGORIES
MATRIX	Residential
	Sugar-cane
	Green area
	Cane crop harvested
	Trail
REGENERATION STAGES	Early sucessional
	Late sucessional
SAMPLING STATIONS HEIGHT	Low
	High
SEASON	Wet
	Dry
MONTH	From September/2017 to September/2018
FRUIT FAMILY	As described in Appendix I
FRUIT SPECIES	As described in Appendix I

For both GLMMs, a data exploration in X's and Y's variables was performed, before the model selection, looking for collinearity, checked by Variance Inflation Factor (VIF) in Package Car version 3.0-2 (Fox et al., 2012) and homogeneity, independence and interactions in different plots, as suggested by Zuur *et al*. (2010). The GLMMs were fitted using Laplacian approximation to maximum likelihood. For the model simplification, it was used *backward* selection approach by removing each variable and using *"anova"* command to compare two models with an analysis of deviance, the variables drop were made using p-values as a reference (Using Package stats version 3.5.1) (Tabachnick, et al., 2007)

After selecting the parsimonious model, Intraclass Correlation Class (ICC) was performed to verify the degree of correlation and agreement between explanatory measurements. ICC helps in understand any aggregation on data that may not be explained by the fixed factors and therefore affects the response variables (Wu, *et al*., 2012; Nakagawa et al. 2017) (Using Package stats version 3.5.1) (Tabachnick, et al., 2007).The p-values reported to each selected model are related to Anova, type III Wald chi-square tests (Using Package car version 3.0-2) and all the inputs are reported in Appendix II.

3.3.3 Fruit consumption behaviour

Because the fruits used on this research needed to be native from Seasonal Semideciduous Atlantic Rain forest, which generally encompasses non-commercial fruits, we were dependent of the weekly fruit acquisition on natural areas, so we are reliant of the fructification phenology, as described in Table 1. Thus, the identity and amount of the fruits

offered weekly were very unevenly and unpredictable, impairing that every AFF receives the same fruits and in the same quantity. In order to Survey Points to be comparative with each other, the total amount of FCV (Fruit Consumer Visits) and PMV (Pulp Masher Visits) were divided per the total amount of offered fruits on each AFF. The values are herein reported as "Fruit Availability Index" (FAF).

3.3.4 Shannon AFF diversity index

It was used a *Shannon index* to calculate the visitation diversity of each AFF in order to have a better understand of the pattern visitation. Then it was performed Spearman rank correlation coefficient test between the "Fruit Index Availability" and the "Shannon Index AFF visitation diversity". Spearman rank correlation was chosen because the data has non-normal error distribution, so a non-parametric test was needed.

4. Results

We recorded 25 frugivorous species belonging to three different taxa (birds, mammals and reptile) that interacted with 21 fruits species belonging to 12 different families, in 36.280 hours of camera trap effort. The most frequent bird and mammal species were *Turdus leucomelas* and *Didelphis albiventris*, respectively. The only reptile species recorded was *Salvator merianae*. Together, *T. leucomelas* and *D. albiventris* performed about 53% of all visits.

Only *Turdus rufiventris* and *Ramphocelus carbo* showed FCV behavior in all their visits. Even though *Colaptes melanochloros*, *Trichothraupis melanops*, and *Turdus fumigatus* are described in the literature as fruit consumers, they were only recorded as NCV visitors. *Tangara sayaca*, *Thlypopsis sordida*, *Piaya cayana* were merely recorded when there was no available fruit on the plate (NFV). Other frugivores had mixed fruit-interactions visits. In *T. leucomelas*, for instance, from 181 visits, 24.3% were NCV; 21.54% FCV; 27.62% PMV and 26.51% NFV. From the 224 visits of *D. albiventris*, 11.60% were NCV; 0.89% FCV; 73% PMV, and 14.28 NFV (Figure 5).

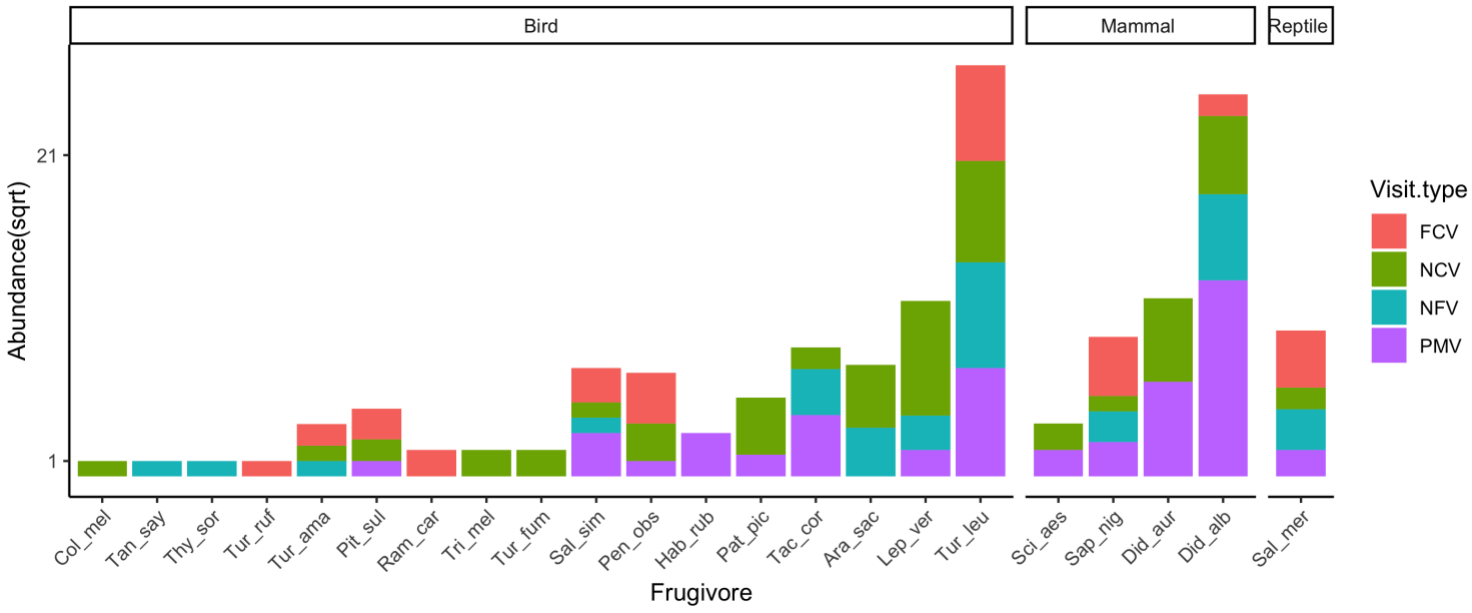

Figure 5: Fruit-interaction behaviour and visiting abundance of frugivores recorded divided by Taxa (N=737). In the y-axis the abundance was square root transformed. Birds: Col_mel: *Colaptes melanochloros*; Tan_say: *Tangara sayaca*; Thy_sor: *Thlypopsis sordida*; Tur_ruf: *Turdus rufiventris*; Tur_ama: *Turdus amaurochalinus*; Pit_sul: *Pitangus sulphuratus*; Ram_car: *Ramphocelus carbo*; Tri_mel: *Trichothraupis melanops*; Tur_fum: *Turdus fumigatus*; Sal_sim: *Saltator similis*; Pen_obs: *Penelope obscura*; Hab_rub: *Habia rubica*; Pat_pic: *Patagioenas picazuro*; Tac_cor: *Tachyphonus coronatus*; Ara_sac: *Aramides saracura*; Lep_ver: Leptotila verreauxi; Tur_leu: *Turdus leucomelas*;Sci_aes: *Sciurus aestuans*; Sap_nig: *Sapajus nigritus*; Did_aur: *Didelphis aurita*; Did_alb: *Didelphis albiventris*; Sal_mer: *Salvator merianae*. Visit type: Pulp Mashing

Visit (PMV), when the animal consumed the pulp wholly or in part but left the seed on the plate; Fruit Consuming Visit (FCV), when the whole fruit was ingested or removed from the tray with the beak, paws, or mouth, beyond the camera field vision; Non-Consuming Visit (NCV), when the animal only smelled or manipulated the fruit in the tray without consuming it; Non-Fruiting Visit (NFV), when the animal visited an empty tray.

The three most significant consumers of different fruit species (considering only FCV visits) are *Sapajus nigritus*, *Turdus leucomelas* and *Salvator merianae*. *Sapajus nigritus* ingested or moved away from the tray more fruit species than anyone else on the study (Myrtaceae: *Eugenia uniflora*, *Psidium sartorianum*, *Campomanesia hirsuta*; Clusiaceae: *Garcinia gardneriana*, *Calophyllum brasiliensis*; Solanaceae: *Solanum diploconos*; Rubiaceae: *Randia armata*) but did not interact (NCV) with Anacardiaceae fruits: *Schinus terebinthifolius*, a 4.14 mm pink fruit. *Turdus leucomelas*, the second greater fruit-eater, consumed Anacardiaceae *Schinus terebinthifolius*, Myrtaceae: *Eugenia cauliflora, Eugenia involucrata, Eugenia observa*, *Eugenia uniflora*, and Arecaceae: *Euterpe edulis*, and do not interact (NCV) with *Calophyllum brasiliensis*, *Cissus verticillata,* and *Psidium myrtoides*. Finally, the third highest fruit-consumer, *S. merianae*, ingested Vitaceae: *Cissus verticillata*, Myrtaceae: *Eugenia cauliflora*, *Eugenia involucrata*, *Eugenia pyriforms*, *Eugenia uniflora,* but refused (NCV visits) *Solanum diploconos* and *Campomanesia hirsuta*. Lastly, in terms of fruit diameter, the FCV visitors exploited different fruit sizes.

It is also possible to observe that these most abundant frugivores mentioned above almost do not overlap on the size of ingested fruits, having a complementary function in the seed dispersion (figure 6). The *P. obscura* was not the most abundant; however, it explores a wide range of fruits, contrasting to *T. leucomelas*, which is more prevailing and uses a restricted and selective range of propagules.

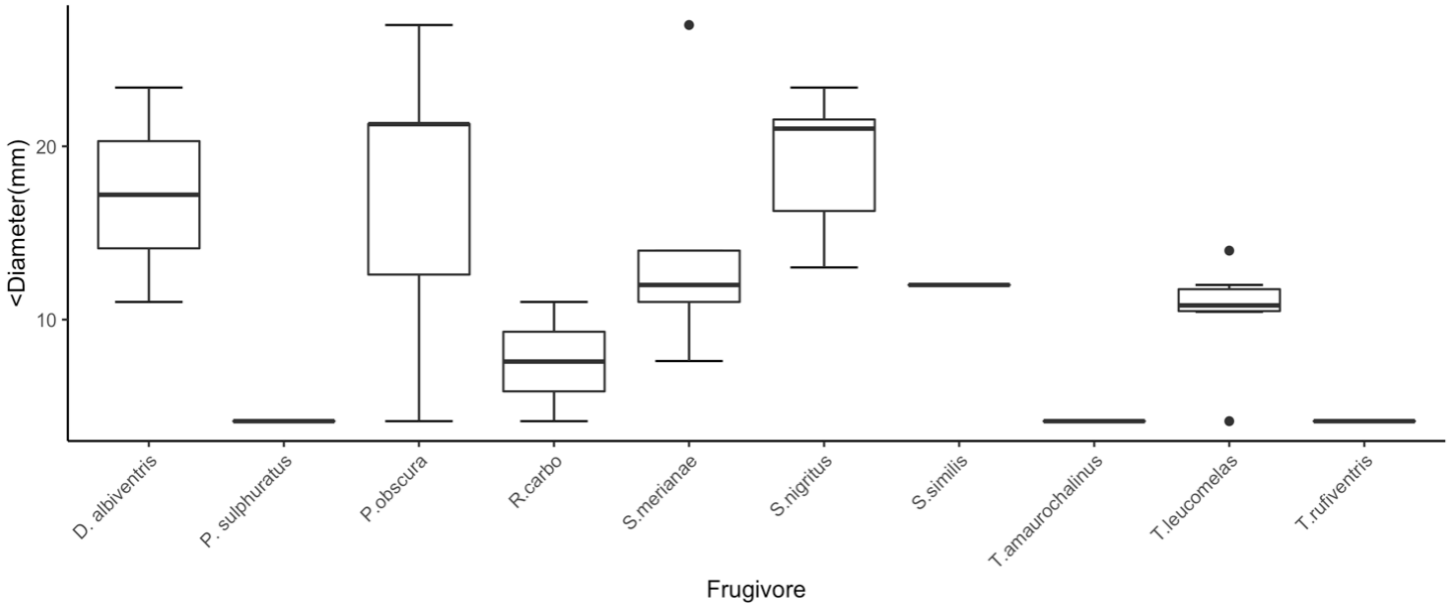

Figure 6 Diameter variation of fruits consumed by the frugivores.D.albiventris: *Didelphis albiventris*; P. sulphuratus: *Pitangus sulphuratus*; P.obscura: *Penelope obscura*; R.carbo: *Ramphocelus carbo*; S.merianae: *Salvator merianae*; S.nigritus: *Sapajus nigritus*; S.simillis: *Salator simillis*; T. amaurochalinus: *Turdus amaurochalinus*; T.leucomelas: *Turdus leucomelas*; T.rufiventris: *Turdus rufiventris.*

In total, 10 animals' species ingested 15 different fruit species with their seeds (FCV visits) (Figure 7).

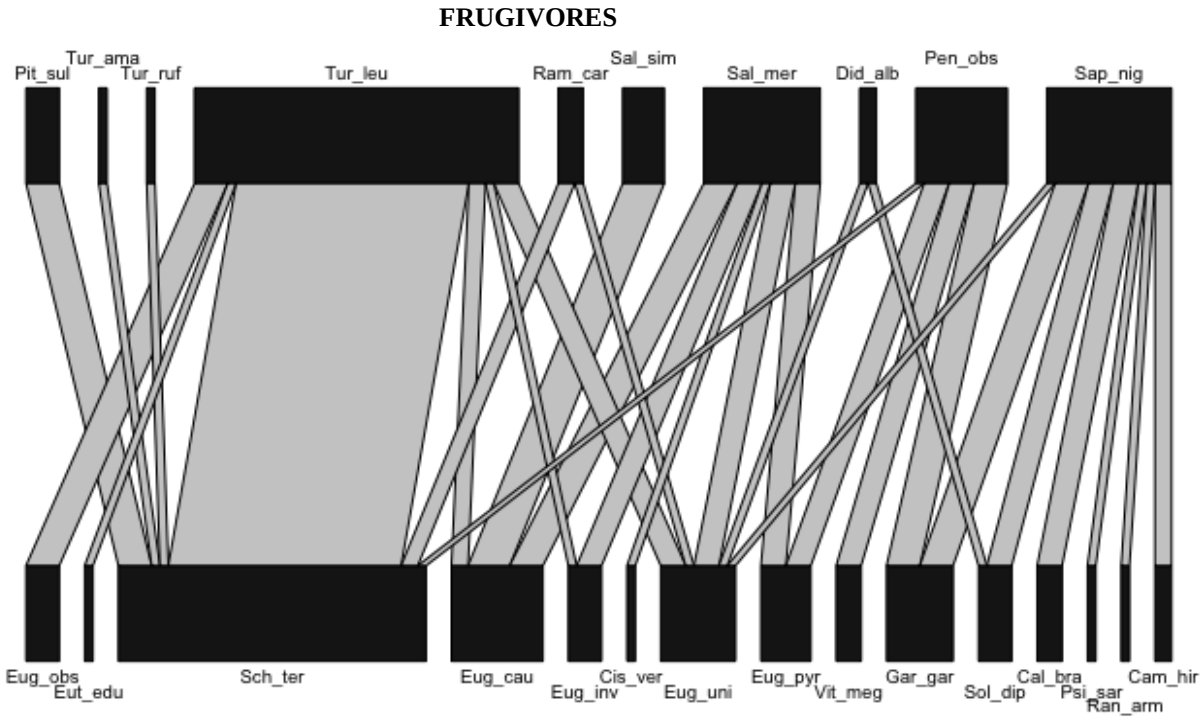

Figure 7: Quantitative network interactions between seed dispersal frugivores and fruits. The size of the bar is proportional to the number of interactions. Superior panes indicate de frugivores. Pit_sul: *Pitangus sulphuratus*, Tur_ama: *Turdus amaurochalinus* ; Tur_ruf*: Turdus rufiventris* ; Tur_leu: *Turdus leucomelas;* Ram_car: *Ramphocelus carbo*; Sal_sim: *Saltator similis*; Sal_mer : *Saltator merianae*; Did_alb: *Didelphis albiventris*; Pen_obs: *Penelope obscura*; Sap_nig: *Sapajus nigritus*. The inferior panes indicate the fruits that were consumed. Eug_obs: *Eugenia observa*; Eut_edu: *Euterpe edulis*; Sch_ter: *Schinus terebinthifolius* ; Eug_cau: *Eugenia cauliflora*; Eug_inv: *Eugenia involucrate;* Cis_ver: *Cissus verticillata*; Eug_uni: *Eugenia uniflora*; Eug_pyr: *Eugenia pyriformis;* Vit_meg: *Vitex megapotamica;* Gar_gar: *Garcinia gardneriana;* Sol_dip: *Solanum diploconos*; Cal_bra: *Calophyllum brasiliense*; Psi_sar: *Psidium sartorianum*; Ran_arm: *Randia armata;* Cam_hir: *Campomanesia hirsuta*.

And 15 animals' species depulped 16 fruits, i.e, pulps are consumed, and seed are dropped on the plate (PMV visits) (Figure 8).

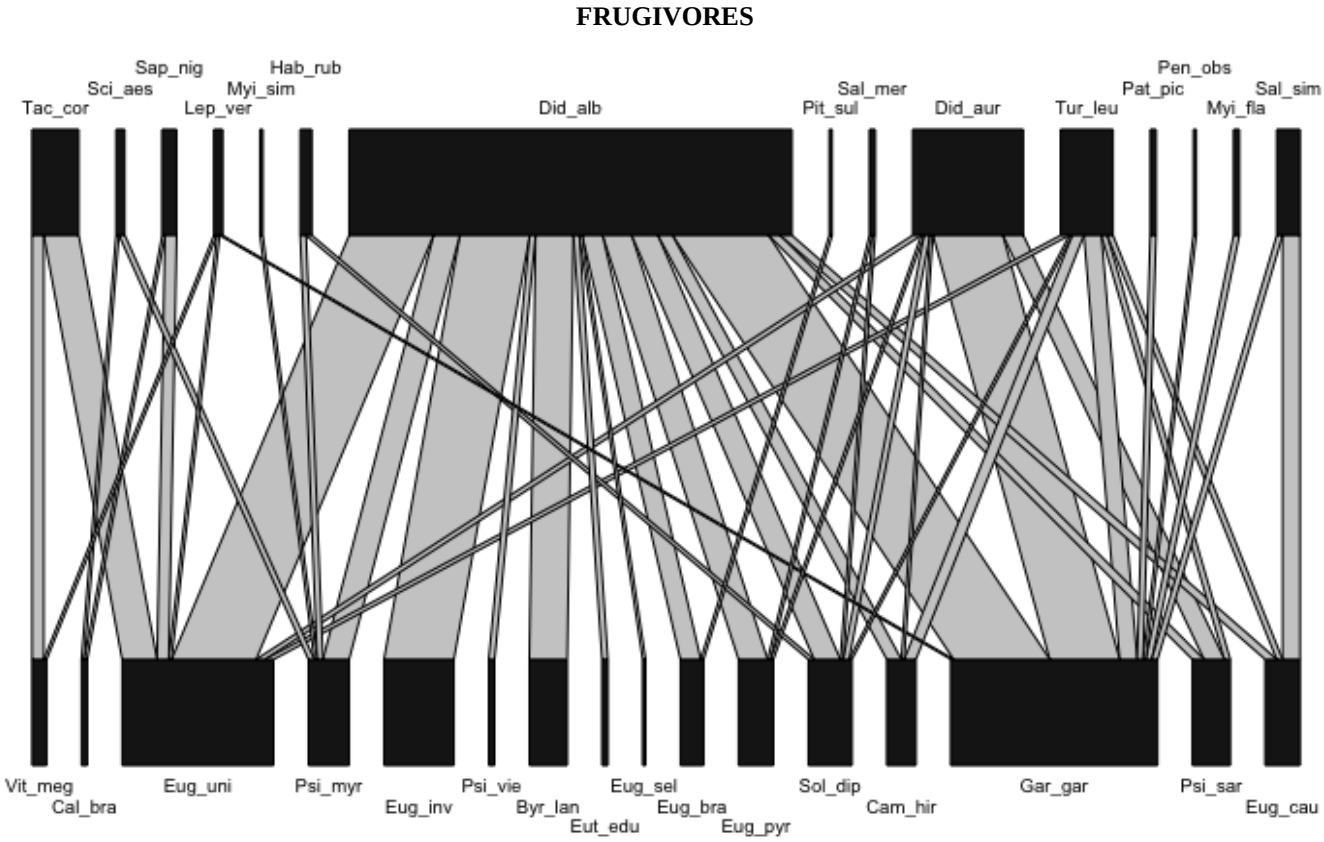

Figure 8: Quantitative network interactions between pulp-mashers and depulped fruits. The size of the bar is proportional to the number of fruit- interactions. Superior panes indicate the frugivores. Tac_cor*: Tachyphonus coronatus;* Sci_aes*: Sciurus aestuans;* Sap_nig*: Sapajus nigritus;* Lep_ver*: Leptotila verreauxi;* Myi_sim*: Myiozetetes simillis;* Hab_rub*: Habia rubica;* Did_alb*: Didelphis albiventris;* Pit_sul*: Pitangus sulphuratus ;* Sal_mer*: Salvator merianae;* Did_aur*: Didelphis aurita;* Tur_leu*: Turdus leucomelas; Pat_pic: Patagioenas picazuro ;* Pen_obs*: Penelope obscura;* Sal_sim*: Saltator similis;* Myi_fla*: Myiothlypis flaveola.* The inferior panes indicate the fruits that were depulped*:* Vit_meg*: Vitex magapotamica;* Cal_bra*: Calophyllum brasiliensis;* Eug_uni*: Eugenia uniflora;* Psi_myr*: Psidium myrtoides;* Eug_inv*: Eugenia involucrata;* Psi_vie*: Psidium virescens;* Byr_lan*: Byrsonima lancifolia;* Eut_edu*: Euterpe edulis;* Eug_sel*: Eugenia selloi;* Eug_bra*: Eugenia brasiliensis;* Eug_pyr*: Eugenia pyriformis;* Sol_dip*: Solanum diploconos;* Cam_hir*: Campomanesia hirsuta;* Gar_gar*: Garcinia gardneriana;* Psi_sar*: Psidium sartorianum ;* Eug_cau*: Eugenia cauliflora*

Some fruit characteristics influence their chance to be removed out from the study stations and may vary according to the animal vectors. SIP (Seed Ingestion Probability) models show that for frugivores in general (p= 0.00375, estimate= 0.013048), Birds only, (p= 0.04870, estimate= 0.009840) and Mammals only (p= 0.0207, estimate= -0.04603), "Fruit abundance" on tray was the most important factor in determining the fruit ingestion. However, just in Mammals, the coefficient model "estimate", i.e, the direction of the found relationship, is negative, indicating that an increase in fruit quantity led to a decrease in seed dispersal (figure 9). And for Reptile, none of all fixed factors were significant.

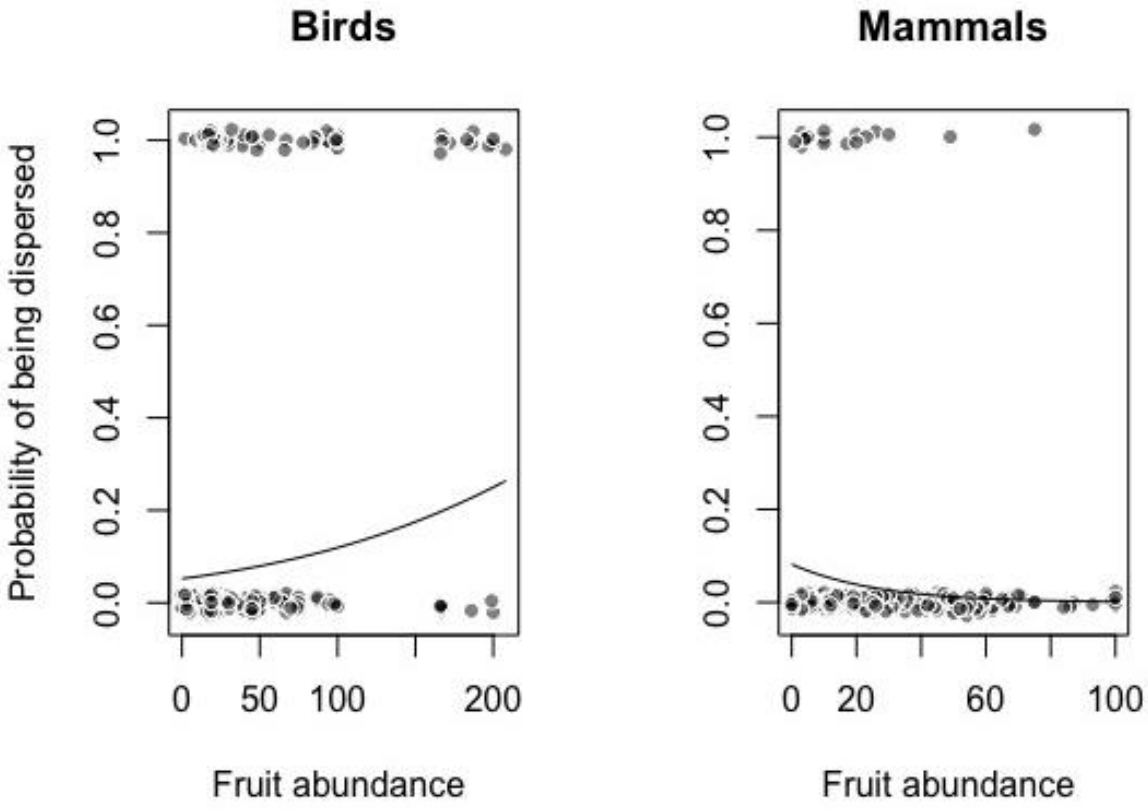

Figure 9: Dotplot bar with a slope and intercepting from GLMM models, indicating the differences between the influence of Fruit abundance on Seed Probability of being dispersed by Birds and Mammals (1=ingested; not- ingested=0)

For *Turdus leucomelas*, an additive influence of seed diameter (p= 0.01757, estimate= 0.5523) and fruit diameter (p= 0.00171, estimate= -0.5957) was identified. In addition, the random variable "Matrix" also influenced *Turdus leucomelas*'s choice (ICC matrix 0.1065), i.e, chances are greater for seed dispersal when a Matrix of "Green" area or a "Trail" were close to them. For *Sapajus nigritus*, not only the variable "Fruit Seed Mass" (p= 5.22e-05, estimate = 38.656) was important but also the variables "Residential Matrix" (ICC= 0.6981), "Dry season" (ICC= 0.1240) and "Family fruit" (Myrtaceae and Solanaceae) (ICC= 0.1774). *Penelope obscura* was influenced by the variable "Fruit Abundance" on the tray (p= 0.0204, estimate= -0.7967) and by the "Green" and "Residential" matrix (ICC=0.8398). Although the propagules

characteristics had no significative influence on the fruit intake for *Pitangus sulphuratus*, the "Matrix", used as random variable (ICC: 0.8473), helped in explaining the residual variance, specifically, the "Sugar-cane" and "Residential" matrix. For the others FCV visitors, it was not possible to perform the SIP models due to small visiting sample size (*Ramphocelus carbo* and *Turdus rufiventris*) or the models with random and fixed effects were not significant to explain the intake (*Didelphis* sp., *Salvator merianae*).

In order to illustrate and integrate the visitation patterns with fruit phenology dynamics in this study site, our data were compared with those on zoochorous frutification reported by Morellato (1991) (figure 10).

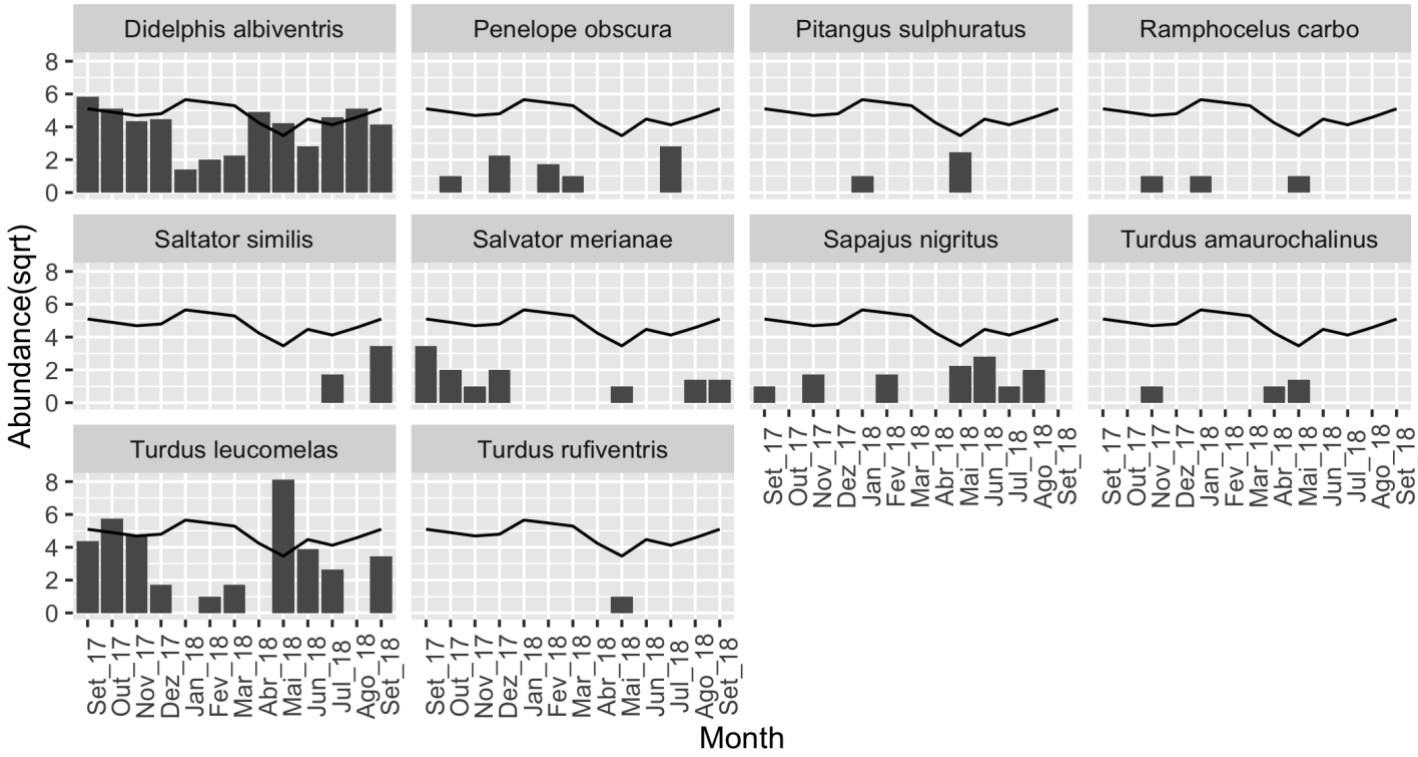

Figure 10: FCV visitors' monthly abundance, sqrt transformed and contrasted with Morellato (1991) fruit phenology line.

As verified by Morelatto (1991), May is expected to be the negative fructification peak at MSG, which also coincides with the highest visitation records of *T. leucomelas*, *P. sulphuratus*, *Salvator merianae*, *S. nigritus* and the unique record of *Turdus rufiventris*. May also list 108 visits, a peak in the entire study, contrasting to March and January, when just three visits were recorded in each. *Didelphis albiventris* and *T. leucomelas* seem to have a constant visitation pattern whereas the visits of *Sapajus nigritus*, *S. merianae*, and *P. obscura* visits are clustered in time. *P. sulphuratus*, *R. carbo*, *S. similis*, *T. amaurochalinus*, and *T. rufiventris* are more opportunistic, with occasional visits at the AFF.

The GLMM selection model indicates that the variable "Tray height" is more parsimonious (*p*=3.63e-06, estimate= |0.4995|, *z value* = |4.632|) for all frugivores in explaining the Space Use Patterns (SUP). The model selected explained 66% of the residual variance (*pseudo* C R^2= 0.66). Post-hoc Tukey test indicated that "Low Tray" had, on average, significantly more visits than high (*p* = 3.63e-06, estimate=0.4995, *z-value* = 4.632) and that the Interclass Correlation Analysis (ICC) indicated the influence of the variables "Fruit Species" (ICC=0.265) and "Month" (ICC=0.101) in explaining the observed result.

For *Turdus leucomelas* the most important Space Use Pattern variable was "Matrix" (T.l: p= 0.00046, Chisq=20.1759. Post Hoc Tukey Test indicated that the "Residential Matrix" and "Cane harvested" (p=0.00112); "Green Matrix" and "Residential Matrix" (p=0.01807) are significantly different from one another. In short, the most visited matrices in descending order were "Residential" > "Sugar-Cane" =" Green" > "Trail" = "Harvested Cane"

Sapajus nigritus visits are explained by the variable "Regeneration stage" (*p*= 0.03355, Chisq=4.5174). Particularly, "Late successional" stages influence positively in the visitation (estimate= 0.6506), whereas "Early sucessional" stages influence negatively (estimate = -1.5669). Also, *Didelphis albiventris* visits respond to "Tray height" (*p*= 0.002221, Chisq=9.3572). "High trays" receive less visitations (estimate=-0.7206), when compares to "Low" ones (-0.7206). For *Salvator merianae*, *Didelphis aurita* and *Leptotila verrauxi*, none of the fixed variables were significant in explaining their Space Use Patterns (p>0.05).

Focusing on the Survey Points individually, it is possible to notice an uneven pattern of visits. For instance, Survey point 45 with 95 records (10 different species, but 75% of all visits are from *D. albiventris*, *T. leucomelas*), and Survey point 50, with 80 records (9 species, 50% from *T. leucomelas*) and Survey point 43 with 74 records, (11 species, 60% from *D. albiventris*, *T. leucomelas*) were the most visited points (Table 1), against the points 44, 36, 27, and 23, which receive, in a year experiment, zero visits (figure 9). Nevertheless, confronting the total individual Survey point records against the Shannon Diverse index reveals that the spots 47, 1, 43 and 30 are the most diverse ones (figure 10).

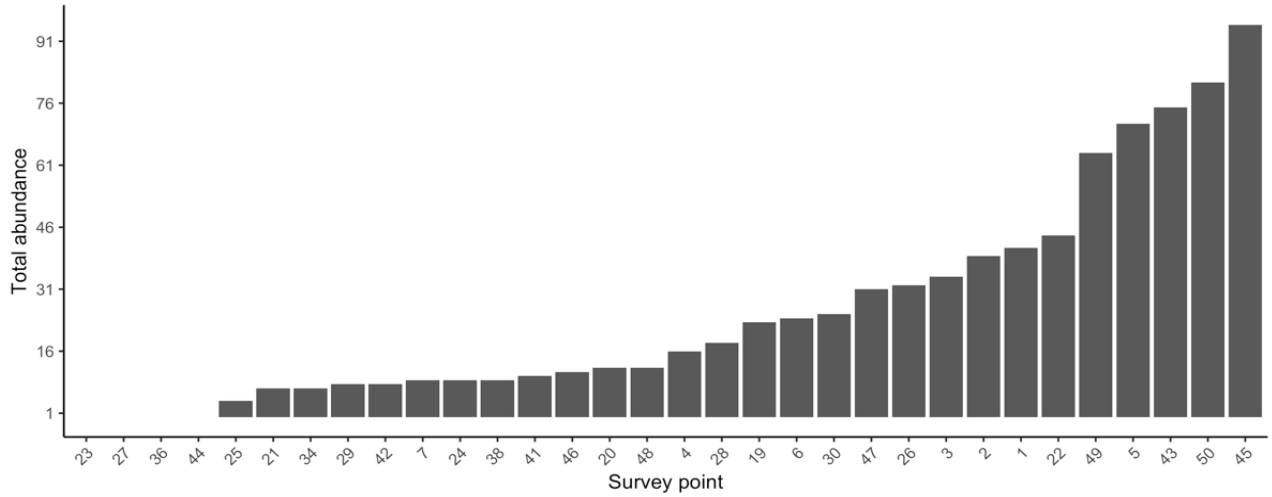

Figure 9: Abundance distribution of frugivores in each Survey point.

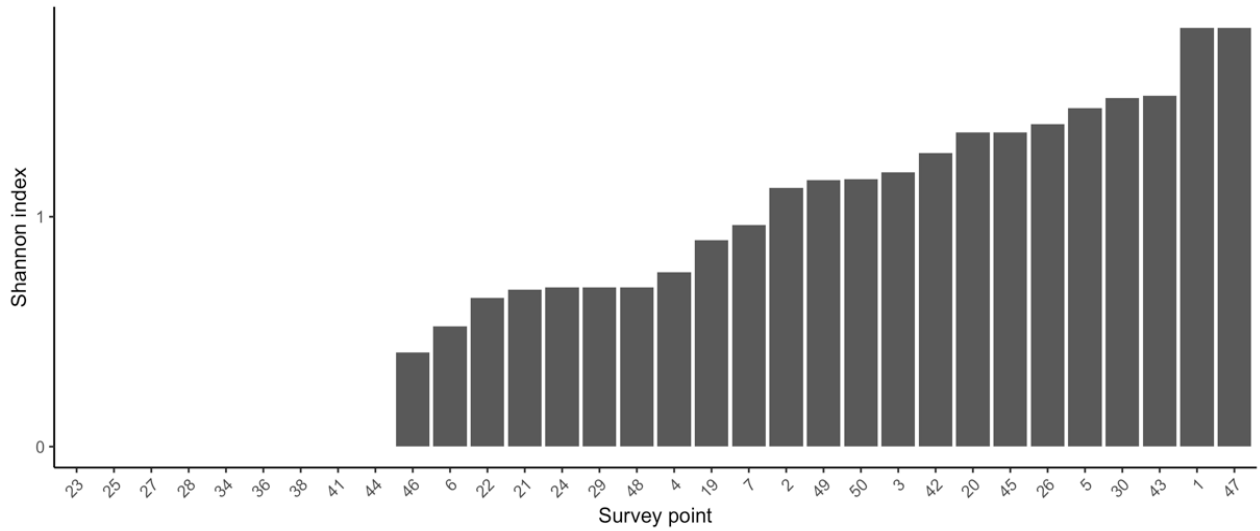

Figure 10: Shannon Index diversity values for each survey point.

Table 2: Species richness and abundance of frugivores, as categorized on the literature, in each Survey point during the 13 months experiment (N=712 visits).

	Survey Points																												
Frugivorous	1	2	3	4	5	6	7	19	20	21	22	24	25	26	28	29	30	34	38	41	42	43	45	46	47	48	49	50	**Total**
Aramides saracura			1	10							2											10			1		3		27
Colaptes melanochloros																												1	1
Didelphis albiventris	2	7		3				17	4	2	32	4		10	11	2	2			9		19	40	7	8	5	33	7	224
Didelphis aurita	2	1	22	1	18	18	1	1															1		1		2		68
Habia rubrica	6																						2						8
Leptotila verreauxi	1	4	1			5	4	1				4		3	2							3	5		3		1		37
Megascops choliba																		2			1	3							6
Mesembrinibis cayennensis											2																		2
Mimus saturninus																						1						2	3
Myiozetetes simillis									1																				1
Patagioenas picazuro																							6						6
Penelope obscura	6		3					1																	3				13
Pitangus sulphuratus											1						4											2	7
Ramphocelus carbo																									1			2	3
Saltator similis	12		1						1					1															15
Salvator merianae			1					3			1			6	1							4	2		5		1		24
Sapajus nigritus									4										1							1	1	18	25
Sciurus aestuans																			6										6
Sylvillagus brasiliensis	1	1										1		7	1							1	1		3		5		21
Synallaxis frontalis											1				1														2
Tachyphonus coronatus		24														1									1			1	27
Tangara sayaca																						1							1
Thlypopsis sordida		1																											1

Moreover, the seed ingestion and fruit depulp ratio have a significant discrepancy amongst Survey points. Despite point 47 has greater Shannon Index, Survey point 50 has a higher intake, which means that there is a greater chance of fruits offered there to have their seeds dispersed (figure 11).

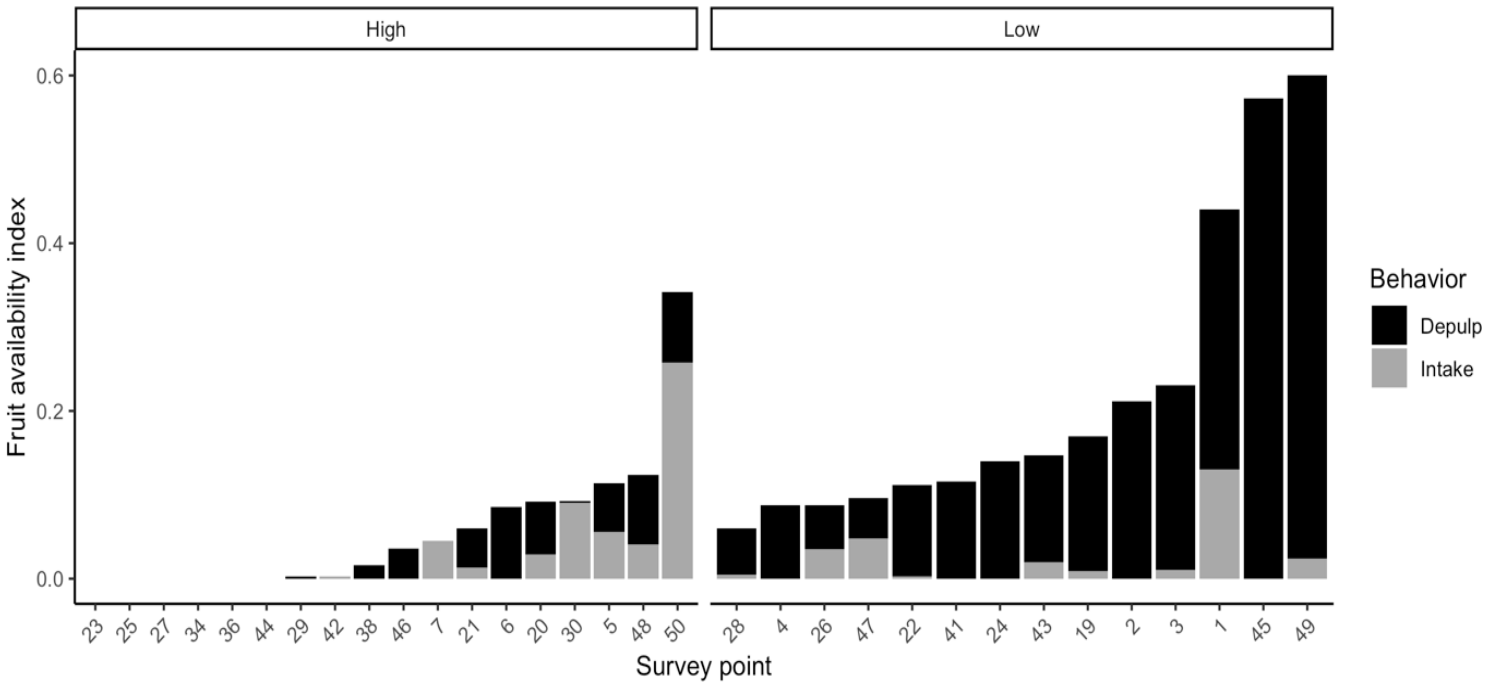

Figure 11: Fruit availability index for (PMV as Depulp) and (FCV as Intake), for each tray, which are dived in High Trays and Low trays

Some singularities and disparities were observed between the most diverse and the most visited trays related to the matrixes that surround them. For instance, Sugar-Cane crops surround Survey Station 45 (AFF at soil level), and it is distant 389.55 m from a highway (Rodovia Gen. Milton Tavares de Sousa), and roughly 1700m distant from a next forest remnant of 110,76 m2. Survey Station 50 (AFF on top) is bordered by residential Matrix (Jardim Novo Real Parque), but also it is influenced by Sugar-cane crop and is 10 m away from a water stream. Survey Station 47 (AFF at soil level) is practically at the same conditions from Survey Station 45. Finally, Survey Station 1 (AFF at soil level), that are encased on the MSG, is less influenced by external Matrix (figure 13)

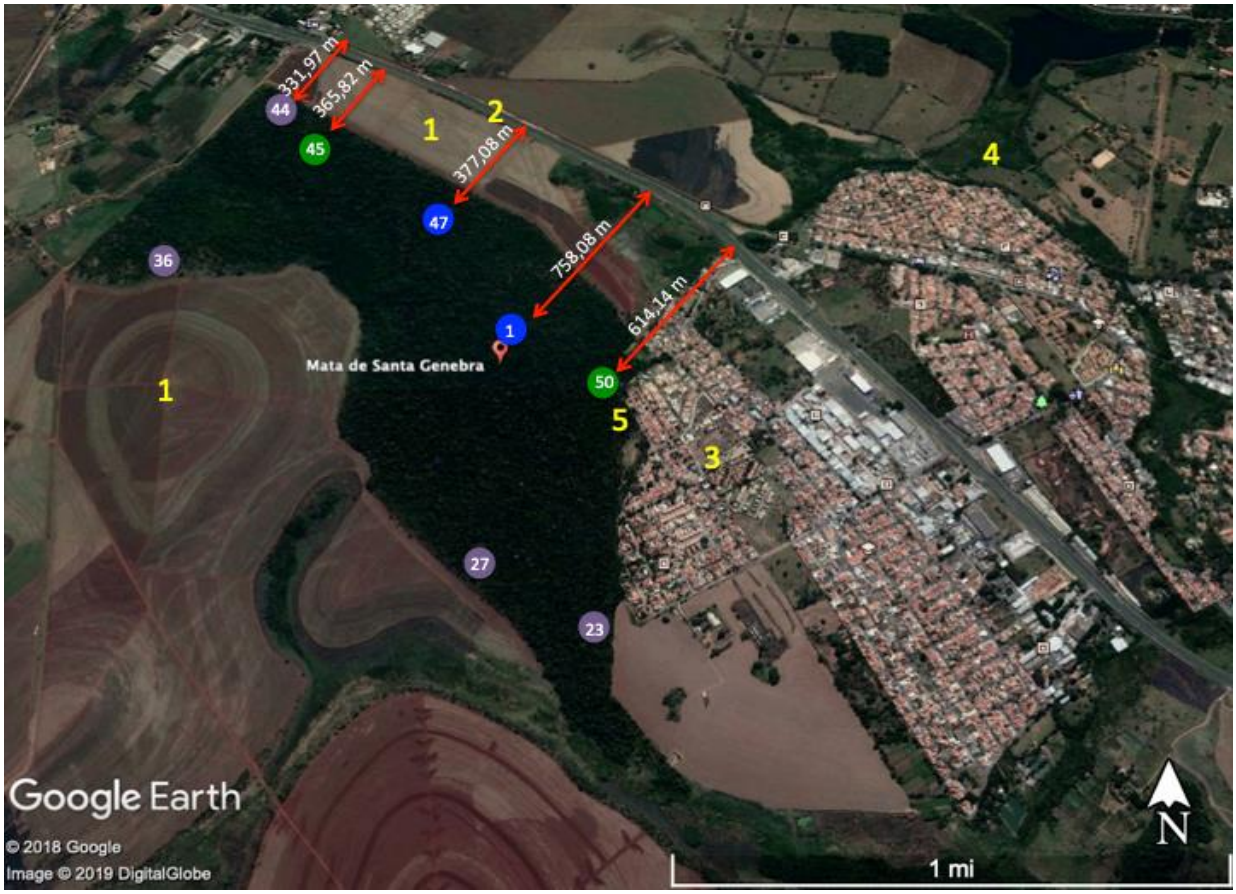

Figure 13: Map of MSG and surroundings. Green circules = most visited survey points; Blue= higher Shannon diversity points; 1= Sugar Cane crop; 2= Highway (Rodovia Gen. Milton Tavares de Sousa); 3=Residential Area (Residencial Real Parque); 4= Forest remmants; 5=Water stream. The red arrows indicate the distance between the Survey points and the Highway.

Spearman rank correlation coefficient test was performed between the "Fruit availability index" and "Shannon Index" of each Survey Station, for two alternatively seed dispersal decision, Depulp (as the total PMV) and Intake (as the total FVC), separately. No significant relationship was found for Depulp (PMV bahavior) (p=0.39), only for Intake (FCV behaviour) (p= 3.543e-06, rho= 0.7190737). Thus, an increase in fauna diversity can lead to gains in seed dispersal quality (Fruit index intake as a seed dispersal quality proxy) (figure 14).

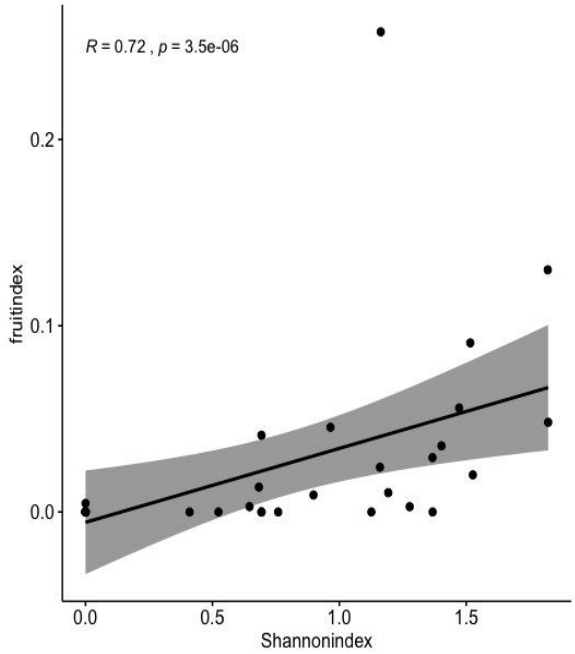

Figure 14: Positive relationship between Fruit availability index (FAF) and Shannon index for intake behaviour.

5. Discussion.

To our knowledge, this is the first frugivory study that has 36.280 hours of camera trap effort in the same study area for one year. Typically, studies carried out in the Brazilian Atlantic Forest can encompass some study sites replicates, however, with a local sampling effort (number of observation points * number of temporal replicates) that varies from 6 to 1540, being 20 minutes the maximum duration per point (Hasui *et al*., 2018). Moreover, in focal observation approaches, sometimes it is hard to differentiate mere visitors, who did not consume fruit, from authentic frugivores, especially in dense vegetation and with non-volant animals (Prasad, 2009), a problem that is overcome in the present research by the use of camera trap records. Furthermore, it is difficult to find frugivory studies that adopted a community approach; they usually focus on a single taxon of animals as the dispersal vectors (e.g., primates, bats, ants, birds), especially in Neotropical studies, and do not consider the entire frugivore assemblages in that ecosystem function (Andressen *et al*., 2018). Finally, only few studies notably consider the matrix as one important feature to explain seed dispersal (Watling et al., 2011; McConkey *et al*., 2012), and that highlights the importance of this study, given that matrix attributes may alter the frugivore behavior, distribution and movement (Gillies *et al*., 2011; Uriarte *et al*., 2011).

The two most abundant visitors, the Pale-Breasted Thrush (*T. leucomelas*) and the White-Eared Opossum (*D. albiventris*) are considered omnivorous, with previous records of fruit eating behavior (Cáceres, 2002; del Hoyo et al. 2005). Fruit can represent up to 90% of *T. leucomelas*'s diet (Gasperin & Pizo, 2009) but can be a more opportunistic food source to *D. albiventris* (Cáceres, 2002). The Pale-Breasted Thrush ingested, in the present study, six different fruit species, mostly *Schinus terebinthifolius*, which is in agreement with previous studies (del Hoyo *et al*. 2005, Cáceres, 2002). Although germination tests were not carried out in this research, the Pale-Breasted Thrush's capacity for maintaining seed viability in its digest tract is highlighted in the literature, as most of the seeds are found undamaged in the feces and also have an improvement in their germination rate when compared to seeds that did not receive the same treatment (Traveset, 1998; D'Avila et al. 2010; Gasperin & Pizo, 2010).

Conversely, *D. albiventris* dispersed only two fruit species and behaved mostly as a PMV visitor, dropping seeds of 14 fruit species on the AFF. Nevertheless, it is important to notice that three of these species are the largest fruits offered in this study (fruit diameter ranging from 18 to 39 mm), *Byrsonimia lancifoliada*, *Eugenia selloi* and *Psidium vienense*, and the opossums interacted exclusively with them. It is possible to speculate that in a defaunated

and degraded fragment as MSG, opossums are the only ones that can provide, at least, a survival chance to large propagules fallen onto the ground by pulp cleaning, preventing microbial damage to seeds and possibly enhancing germination and delivery, offering, therefore, a marginal seed dispersal function (Travesset-Rodriguez-Pérez, 2007, Cantor et al, 2013). This happens because plant species that have a large fruit size could only be dispersed by few specialized dispersers with a large gape (Cordeiro et al., 2009); since the large frugivores are absent in depauperate areas, this plant species can have reduced fruit removal rates and a decrease in the dispersal kernels (McEuen and Curran, 2004).

Furthermore, it is possible to take advantage of the opossum's high abundance in degraded areas and employ them as supporters in restoring depauperate natural areas, using, for instance, the Induced Seed Dispersion (ISD) technique developed at the Laboratory of Vertebrates-Plants Interactions (Silva et al. in prep.). Such technique consists of inserting small seeds of selected species in attractive fruits, such as Banana (*Musa* sp.), which are offered to local residual frugivores that can ingest and disperse hundreds of seeds in the environment. The opossum is one of these resilient frugivores, a species with a well-documented potential in dispersing small seeds viable for germination (Hale & Swearer, 2017; Cantor et al., 2013 Caceres, 2002).

Some potential frugivores, as described in the literature, such as Green-barred woodpecker (*Colaptes melanochloros*), Cocoa thrush (*Turdus fumigatus*), Black-goggled tanager (*Trichothraupis melanops*), Slaty-brested Wood-rail (*Aramides saracura*), Ruby-crowned Tanager (*Tachyphonus coronatus*), Picazuro Pigeon (*Patagioenas picazuro*), and Red-crowned Ant-tanager (*Habia rubica*), only performed non-consuming visits (NCV). However, the consuming avoidance by the frugivores mentioned above is not intuitive, mainly because some of them only occurred from May to July, the period of lower availability of fruits and insects in Tropical Forests (Terborgh, 1986; Galetti, 1993). This could be explained by two main reasons (i) neophobia, i.e., fear of anything new, especially because some of the offered fruits are not existent in the fragment; (ii) the fruit disposal on AFF, which could be unusual or not attractive to them (Greenberg, R. & Mettke-Hofmann, 2001).

5.1 Frugivores Seed Ingestion Probability (SIP Model)

The GLMM performed to determine seed ingestion probability by the frugivores found an influence of fruit aggregation, i.e., the quantity of propagules disposed on the AFF. Nevertheless, the estimate values from GLMM test indicated an ambivalent relationship between avian and mammalian frugivores. In birds, there is an increase of seeds ingested in the visits when there are more fruits on the AFF, and for mammals, the relationship is inverse. For

birds, such relationship could be addressed to behavioral and physiological aspects, e.g., neophobia: when more fruits are placed on the AFF, it possibly produces a signal of a less dangerous resource than a single or few new specimens (Greenberg, R. & Mettke-Hofmann, 2001).

Additionally, the fruit aggregation may emphasize the fruit coloration, making them more conspicuous for visually-oriented birds and, as most of the avian species that attended our AFF are legitimate seed dispersers, more visits means more seed ingestion (FCV visits). For mammals, more fruits could also represent a strong visual stimulus, besides creating a powerful aroma bouquet that could attract more visitors, such as *D. albiventris*, a superabundant mammal at the study site that delivers a pulp mashing service and could bias the models. Indeed, the only mammal that performed FCV (Fruit consuming visits) was the Black-capped capuchin.

5.2 Frugivorous Space Use Patterns (SUP Model)

The Space Use Patterns models suggest that "Feeder position" significantly impacts the way visitations can be explained. Accurately, low trays receive more visits, and this could be biased by the superabundant *Didelphis* sp, that prefers to use the tray at ground level. However, it is intriguing that the feeder height influences more than “Matrix type” and “Conservation status”, features that are considered central to explaining species distributions in fragmented areas (Boesing et al., 2018; Melito et al., 2018; Umetsu, et al., 2008). Some of the explanations could be attended by the fact that generalist frugivores compose most of the faunal assemblage, i.e., those able to subsist in the absence of a particular fruit and accept a considerable variability of habits and conditions (Snow, 1971; McKey, 1975). Definitely, the most abundant visitors are considered generalists, such as *D. albiventris*, *D. aurita*, *T. leucomelas*, *Salvator merianae*, and *Tachyphonus coronatus*, which can lead to broader distributions and space use, making the tray height a critical and, possibly, single visit-limiting barrier, reinforcing their importance to the target the fauna sought in forest restoration processes.

"Fruit species" and "Season", taken as random variables, could also affect the frugivores’ space use patterns. Species such as *Byrsonima lancifolia* (MALPIGHIACEAE), *Eugenia uniflora* (MYRTACEAE), *Sorocea bonplandii* (MORACEAE) and *Eugenia pyriformis* (MYRTACEAE) have a positive bias in overall visitations, which means that for some reasons they attract more frugivores than expected according to their abundances. It is interesting that these fruits can attract frugivores even in the wet season, when fewer visits were recorded due to more fruit availability at the study site (Morelatto, 1991). Morphologically, *B. lancifolia* and *E. pyriformis* are yellow, and *E. uniflora* and *S. bonplandii* are red/black, colors

well described in the literature as attractive to primates and avian seed dispersers (Larrinaga, 2011; Borgia & Keagy, 2006; Cazzeta, 2008; Puckey & O'Dowd, 1996). Furthermore, chemical characterization of these fruits from preceding studies (Jordano, 2007; Karwowski *et al*., 2013) indicates low levels of lipids – less than 10% of dry mass –, which are good predictors of fruit removal by frugivores, being related to attracting more non-obligate frugivore (Cazzeta, 2008, Pizo, 1997). Thus, it is possible that fruit physical and chemical content might influence the bias caused by such propagules on the overall visits.

The variable "Season" also influences the Space Use Pattern. This happens because more visits were recorded on the dry season. Morelatto (1991) reported 109 fruiting species with the zoochorous syndrome at MSG, with fruit peak in September and a negative peak between April and May. Although these values could be outdated due to the increased process of anthropogenic disturbances in and around MSG, such as fragmentation and fire events in the last 20 years (Farah *et al*., 2014), they still constitute a good portray of fructification phenology since the observations were made *in situ*. The negative fructification peak included the most visited month with 108 records, showing the classic natural pattern for frugivores (Terborgh, 1986; Galetti, 1993). *Salvator merianae*, *P. sulphuratus*, *S. nigritus*, and *T. rufiventris* were absent from our records (except for the latter, which was recorded once) for at least two months prior to the negative fructification peak, and then reappeared on the AFF thereafter. These four species are described on the literature as reliable seed dispersers i.e, seed viability is maintained throughout their digest tracts and the fruits are moved away from the parent plants. Indeed, the mentioned species did perform FCV behavior during the experiment, indicating that legitimate seed dispersing visits increase during fruit scarcity periods. Thus, an adequate forest management that includes fruit enrichment can take advantage of this period, to input flora species of interest in the fragment, since less preferred fruits are forcefully consumed when preferred fruits are a limited resource in the area (Morris, 1989).

GLMMs of Seed Ingestion Probability (SIP) and Space Use Patterns (SUP) indicated species-specific differences, showing that different fruit traits are related to fruit ingestion, and that Space attributes explain the Visitations patterns of the four most frequent fruit consumers, which are *Sapajus nigritus*, *Turdus leucomelas*, *Salvator merianae* and *Penelope obscura*.

5.3 *Sapajus nigritus*

The Black-capped capuchin (*Sapajus nigritus*) consumed the largest variety of fruits, in total 7 species from 3 different families (diameter ranging from 16.06 to 21.72 mm), an

expected result considering that fruits can encompass a high fraction of their diets, reaching up to 89% (Galetti and Pedroni, 1994; Mikich, 2001). Seed mass influenced the propagules ingestion positively, so seeds with higher mass have more chances to be dispersed by *S. nigritus*. The detection of traits that influenced the Black-capped capuchin's fruit choice in a statistical model is a new contribution of the present study, because no such information has been elucidated on literature yet (de Almeida *et al*., 2018).

Additionally, we also identified that "Residential" matrix positively biases the chances of seed ingestion. One possible reason is related to the occurrence and survival of the capuchin in small forest remnants that are normally surrounded by an anthropogenic modified landscape, as other food sources, like orchards, sugar-cane plantations and corn crops, can be found to complement their diets during food shortages (Ludwing et al., 2006; Mikich and Liebsch, 2014a). Furthermore, the author personally observed what the MSG neighborhood residents often report Human-Primate conflicts in the residential matrix, with *S. nigritus* groups invading the nearby houses for food robbery. Techniques of environmental enrichment through fruit supplementation, as used in this experiment, combine both management practices and social aspects in order to minimize the damages caused by capuchins in plantations and residential areas, since their occurrences on such matrixes are proportionally inverse to the availability of native fruits in their natural habitats (Mikich & Liebesch, 2014b). Moreover, the dry season influences positively the chance of seed ingestion due to the usual food shortage in the Atlantic Rain (Galetti, 1993), leading the capuchins to perform high quality seed dispersal functions during that period.

Finally, the SUP model indicates that the conservation status of the forest influences *S. nigritus* occurrence. Late successional stages were preferred, which can be explained by the Black-capped capuchin's arboreal and social behavior. Early successional stages of the MSG have more sparse and small trees, and less complex habitats, making them unattractive for the capuchin.

5.4 *Turdus leucomelas*

The second greater fruit consumer was the Pale-breasted Thrush, consuming and dispersing six species propagules from 3 families (diameter ranging from 4.14 to 13.98 mm). We found that an increase in fruit diameter leads to a decrease in the chance of seed ingestion, which is plausible since most fruit-eating birds are gape-limited (Zaret, 1980). However, an inverse relationship for seed diameter leads to a greater chance of seed ingestion. This could be explained by the low pulp/seed ratio found in some fruits consumed by them, such as *Euterpe edulis* (pulp/seed ratio = 0.15) and *Schinus terebinthifolius* (pulp/seed ratio = 0.20). The

consumption of small fruits with less pulp and big seeds by this thrush species biased the models analysis. Moreover, "Green" matrix area favors SIP, and SUP indicates that the overall visits are more influenced by "Residential" matrix, i.e, *Turdus leucomelas* are more often seen close to urban areas than in more forested areas. Such apparent duality between the models could be explained, in part, by their generalist habits, with a high capacity for crossing different matrices, and by their low sensitivity to disturbance, expressed in their medium forest dependence, enabling them, in their incursions on natural areas, to explore shelter and complementary food sources, such small fruits, usually unavailable in urban areas (Emer *et al*., 2018; Pizo, 2004; Gasperin & Pizo, 2009).

5.5 *Salvator merianae*

The Black and white Tegu (*Salvator merianae*) was the third largest fruit consumer, eating five fruit species from 2 families (diameter ranging from 7.61 to 27 mm), which is less than found by Castro & Galetti (2004). The role of lizards on the seed dispersal process are commonly reported in islands (Whitaker, 1987; Valido & Nogales, 1994; Travesset, 1995; Traveset & Riera, 2005; Pérez-Méndez & Jordano, 2016), where they can be the largest frugivores. According to Travest (1998), from 41 seed species consumed by lizards, 56% were not affected in their germination rates, and 28% showed and positive effect. Likewise, in 63% has their germination velocity altered, where 47% suffered an increase.

SIP model found no significance of any fruit trait in *S. merianae*'s choice, but ICC analysis showed different influences of Months on visitation. For instance, month influence was positive in September (2017), October (2017) and September (2018) and negative in May (2018) and August (2018), probably due to brumation, a dormancy period of minimal metabolic activity affecting reproduction and foraging activities (Beolens & Grayson, 2011). This behavior occurs in cold months, such as May and August; by the other hand, September and October are months when the temperatures start to rise again, and there is the resumption of normal metabolic levels.

There was no significance in the fixed variables to explain the Space Use pattern. Despite this seasonal difference in behavior, the Black and white Tegu can be a useful species in restoration, which is an important found of the present study because, typically, reptiles, in particular from Order Squatama are underrepresented in frugivory research, with more registers of Testudines (Corlett 2017; Traveset & Verdú, 2002).

5.6 *Penelope obscura*

The Dusky-Legged Guan (*Penelope obscura*) ate 4 fruit species: (*Schinus terebinthifolius* (ANACARADIACEAE), *Eugenia pyriformis* (MYRTACEAE), *Garcinia gardneriana* (CLUSIACEAE) and *Vitex megapotamica* (LAMIACEAE), which means more fruit species than the number found by Pizo (2004) for *P. supercialiaris*, and fewer than what Mikich (2002) and Vasconcellos-Neto (2015) observed for *P. obscura*. The seed diameter of the consumed fruits reached 28.52 mm, which is larger than reported by Vasconcellos-Neto (2015). "Fruits Abundance on Feeders" has a significant negative influence, i.e., more propagules on the tray represent fewer chances of a legitimate visit. Although there is no clear explanation for this pattern, neophobia, fruit disposal, and satiation may influence and act synergistically in explaining consumption behavior (Greenberg, R. & Mettke-Hofmann, 2001). Moreover, the absence of a gizzard aims keeping seeds undamaged in the feces (Guix, 2006), indicating *P. obscura* as a legitimate seed disperser, even in small forest remnants, where they can be one of the largest resilient frugivores that explore an array of small and large fruits (Aleixo & Vielliard, 1995; Mikich, 2002, Zaca *et al*., 2006).

Also, the "Green" and the "Residential" matrices negatively influence seed ingestion, which can be associated with fruit satiation in these areas. In Green areas, they may find enough food such as fruits, shoots and leaves in the forest, therefore, diminishing visits to AFF and, consequently, seed ingestion in general (Ottoni et al., 2009). In the Residential Matrix, it is possible that they can obtain anthropogenic food, such as corn and leftovers (e.g., rice, beans), leading to a decrease in food search and, consequently, to the seed dispersal functions they perform (Vasconcellos-Neto 2015).

The SUP model found no significant trait to better explain the *P. obscura*'s distribution. Nonetheless, visits were just recorded at low-level trays, mostly because adults joined by juveniles, a group that was excessively large to perch on the single high-level MDF tray, did most of the visits. The peak visitation was in July, during the dry season, which is a period of low fructification at the study site, a predictable pattern considering that frugivorous visits are related to the abundance and variety of natural resources (Franscisco *et al*., 2007). Zaca *et al* (2006) observed the same visitation pattern for *Penelope superciliaris* in fragmented areas.

5.7 Survey Station visiting pattern

The most visited survey stations (survey stations 50 and 45) and the highest Shannon index diversity of visitors (survey stations 1 and 47) had some similarities and discrepancies,

either regarding the identity of the visiting fauna or the habitat-related and matrix features. The Survey Station 50, a high AFF, was surrounded by a mosaic of urban areas with houses and rural areas with a sugar cane crop, where *Turdus leucomelas* and *Sapajus nigritus* were the most abundant visitors. Survey Station 45, a low AFF, was near a sugar cane crop and a highway. The two generalist super-abundant visitors, *Turdus leucomelas* and *Didelphis albiventris* together composed 57% of the visits. The remainder visitors belonged to 8 species, one of them considered a legitimate seed disperser, *Salvator merianae*, and another one, a top predator *Leopardus guttulus*. As the most diverse ones, Survey Station 1 was located inside the MSG, had a low tray and was visited by nine animals, seven of them were frugivores, being *Saltator similis* the most common one. Nevertheless, data from this Survey Station exhibited a cluster on a general visitation pattern from July to September. Survey Station 47 had the same Shannon index diversity compared do Survey Station 1, being adjacent to sugar cane plantations and less than 200 m away from a highway.

It is intriguing that the AFFs with the highest animal diversity and abundance were bordered or close to the most anthropogenic side of the study area, contradicting the relationship between abundant visits and low-level anthropogenic influences pointed out by Staggemeir and Galetti (2007) and many others. This unobvious visitation pattern highlights the importance of urban forest fragments in harboring locally endangered and/or resilient species, preventing them from going locally extinct (Wintle *et al*., 2019, Estevo *et al*., 2017, Nowak &Walton, 2005). Wintle *et al*. (2019) stated that the disproportional importance of small remnant habitats in containing more rare and unique biodiversity. Which may be irreplaceable when compared to less anthropomorphized areas of similar equivalent size, as its fauna may provide critical ecosystem functions for the remnants themselves and sustain human health and environmental quality in the surrounded urban and rural areas through the provision of ecosystem services such as seed dispersal, pollination and pest control (Naeem, 2009; MEA, 2005). Urban forest importance will sharply increase with the continuous expansion of urban zones over natural ones, making some of these ecosystem services progressively rare (Nowak & Walton, 2005). Therefore, the preservation of these areas need to be prioritized by city managers, planners and councilors in big cities and especially in the remnants of Brazilian Atlantic Rainforest, a biome that is home to 100 million Brazilians and is responsible for 70% of the Brazilian gross domestic product (GDP) (Martinelli *et al*., 2013).

Curiously, Survey Stations 23, 27, 36, and 44, all consisting of a high tray, did not receive any visitors at all during the experiment. The ICC tests revealed no bias caused by the offered fruit species. Indeed, one of the most consumed fruits on this study, *Schinus*

terebinthifolius, was available on Survey Station 23, as well as many other heavily consumed fruits of Myrtaceae, such as *Eugenia cauliflora*, *Eugenia brasilensis*, *Psidium myrtoides*, *Eugenia uniflora*. Moreover, the ICC test did not show any difference in the sampling effort in any season, i.e., all seasons were evenly sampled. The absence of visits to these Survey Stations, beyond those mentioned above (neophobia and fruit disposal on feeders), can be alternatively explained. The AFF height, in some cases 1.8 meter above ground, could be inconspicuous to some aerial and/or arboreal frugivores, such as the Howler monkey (*Alouatta guariba clamitans*), a large primate that has a partly frugivorous diet and occur in small numbers at MSG (Mendes 1989; Chiarello 1994). Howler monkeys can consume some large-sized fruits such as *Eugenia pyriformis* and *Jacaratia spinosa* (Martins, 2006), which were offered in the experiment, but received, mostly, a low quality seed treatment (e.g. pulp mashing behavior) The Survey points 23, 27 and 36 are inside areas that have recently suffered with arson and are now undergoing the initial stages of regeneration, which can diminish the overall visitation due to lack of perching structures to stop and rest, and resources such as fruits (Holl, 1998). The risk of predation could also keep these primates out of this area, since open areas increase the exposition to predation (Graham & Page, 2012).

The use of AFF in areas of initial restoration could be improved by increasing the number of such structures. For example, AFFs numbers 23, 27 and 36 were, unintentionally, separated by more than 400 m, so the resource disposal were sparse and less attractive (Athiê & Dias, 2016). Our study showed a pattern visitation and fruit consumption by some frugivorous species that can be transformed into practical actions, for instance, the offering of more fruits and seeds in the dry season or the investing in small fruits, such as *Schinus terebinthifolius*, to attract more reliable seed dispersers, as *Turdus leucomelas*. Additionally, the use of AFF laid on the ground, depending on the purpose and species of interest to be dispersed, could be attractive to more generalist, abundant and fearless ground-dwelling frugivores, such as opossums, that can provide faster seed dispersal service.

Furthermore, a positive relationship between frugivores diversity and effective visits was detected, i.e., higher diversity leads to an increase of FCV, a proxy of seed ingestion and seed dispersal function quality. The same relationship was found in previous studies by García & Martinez (2012) for Ugandan and Spanish frugivorous birds; Tellería *et al*., (2014) for thrush (*Juniperus thurifera*); McConkey, Brockelman (2011) for Primates (*Macaca leonina* and *Anthracoceros albirostris*) and Carlo *et al*. (2013), for birds in Spain. This pattern could be explained by understanding the functional consequences of biodiversity, i.e., different numbers and kinds of species are related to the organismal's traits, for example gape width in frugivorous

birds, which lead to different ecosystems processes, for instance, the capacity for dispersing fruits of different sizes, such as *Penelope obscura*, which can ingest even the large ones (Naeem, 2009). Trait expression is determined by species richness, evenness, composition, interaction and temporal and spatial variations (Tilman et al., 2001, Naeem, 2009). Considering that there is a relationship between biodiversity and ecosystem function, three main hypotheses proposed by Lawton (1994) and Naeem et al (1994, 1995) could explain this pattern: (i) Sampling effect: the probability of a community to include some functionally important species increases with the species richness; (ii) Niche complementary effect: diverse assemblages contain a greater number of functional groups, so they function more efficiently, and (iii) Biological insurance: the higher the species richness, the greater the functional redundancy, so that species can be lost without loss of function (Loreau & Hector, 2001).Therefore, a community with more frugivores can lead to higher quality seed dispersal services (Jordano *et al*., 2007). Additionally, given that studies reporting a relationship between frugivory diversity and seed dispersal quality in a multi-taxon frugivores assemblage in tropical forests are rare, the technique applied in this study can provide extra resources to attract fauna and use the animals as seed dispersal agents to an area and its surroundings, promoting biodiversity in the urban ecosystem (Estevo et al., 2017).

Finally, this research re-emphasizes the importance of applying legal protection measures to natural areas, like Mata Santa Genebra, which are in jeopardy under the current Federal Brazilian Executive and Legislative administration due to the process of the dismantlement of Brazilian environmental laws and the public environmental agencies such as the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and the Chico Mendes Institute for Biodiversity Conservation (ICMBio) (Nature, 2018, Abessa *et al*., 2019; Artaxo, 2019; Skinner & Milward-de-Azevedo, 2019).

6.0 Conclusion

This study stresses the importance and the potential of the residual fauna on the process of reversing the flora impoverishment in defaunated forest fragments in the realm of the Brazilian Atlantic Forest, which is currently composed of small and isolated remnants. The use of Artificial Fruit Feeders (AFF) showed to be worth in the potential enrichment. Nevertheless, species-specific management proves still necessary due to singularities regarding Space Use Pattern and nutritional requirements of each frugivore, as well observed in this study. Specifically, much attention needs to be addressed to the surrounding non-habitats, the matrices, which are capable of altering patterns of food consumption and distribution. Finally, this study reinforces the significance of urban forests in providing shelter, food, space to rest, to many animals. Without such place, many species could be locally extirpated, bringing many consequences to the forest fragments and the surrounding urban areas, through the loss of many ecosystem services.

7.0 References

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Appendix I: Morphometrics of the fruit species used in the experiment. The values are related to mean values for 10 specimen samples.

Family	Specie	Total mass (g)	Seed mass (g)	Pulp Mass (g)	>Fruit Diameter (mm)	<Fruit Diameter (mm)	Seed number	>Seed diameter (mm)	<Seed diameter (mm)
MYRTACEAE	*Eugenia brasiliensis*	1.97	0.30	1.67	16.53	13.33	1.8	8.77	5.71
MYRTACEAE	*Eugenia selloi*	14.09	2.32	2.45	39.48	26.18	1.16	18.54	11.59
MORACEAE	*Soroceae bomplandii*	1.68	0.40	0.43	14.23	13.09	1	10.17	6.74
PRIMULACEAE	*Stylogyene depauperata*	0.33	0.048	0.28	10.45	7.157	1	4.79	4.59
CARICACEAE	*Jaracatia spinosa*	62.77	2.01	60.76	61.14	40.49	119.5		2.81
CLUSIACEAE	*Garcinia brasiliensis*	5.68	0.91	4.78	22.04	21.28	1.9	14.50	6.32
MYRTACEAE	*Psidium myrtoides*	3.72	0.35	3.38	19.25	17.10	7.2	5.25	3.48
MELASTOMATACEAE	*Leandra australis*	0.272	0.028	0.244	8.52	8.12	133.7		
RUBIACEAE	*Randia armata*	5.82	0.73	5.09	27.20	18.56	16.4	6.66	1.82
MYRTACEAE	*Campomanesia hirsuta*	18.29	0.30	17.99	36.31	21.82	15.75		
CALOPHYLLACEAE	*Calophyllum brasiliense*	4.30	1.52	2.78	21.74	21.02	1	17.01	16.59
RUBIACEAE	*Guettarda poliana*	0.81	0.52	0.30	15.87	8.88	1	14.19	7.28
MYRTACEAE	*Eugenia observa*	1.25	0.55	0.70	14.97	10.62	1.1	11.92	7.57
MYRTACEAE	*Psidium sartorianum*	1.43	0.17	1.27	13.05	13.01	8.8	4.32	2.17
MYRTACEAE	*Eugenia candolleana*	4.37	0.81	3,56	20.99	18.56	1.9	13.05	6.75
MYRTACEAE	*Campomanesia sessiliflora*	9.96	0.023	9.94	27.56	23.26	3.6	3.50	1.61
MALPIGHIACAEAE	*Byrsonima lancifolia*	3.94	0.48	3.46	18.82	19.00	1	9.13	9.11
SOLANACEAE	*Solanum diploconos*	9.81	0.39	9.42	30.41	23.39	109.5		0.85
VITACEAE	*Cissus verticillata*	0.249	0.036	0.213	7.61	7.24	1	5.15	3.59
MYRTACEAE	*Eugenia cauliflora*	3.67	0.2	3.47	12.1	11.9	1	7.08	5.83
MYRTACEAE	*Eugenia uniflora*	1.32	0.359	0.961	11.02	9.03	1	9.09	8.17
LAMIACEAE	*Vitex megapotamica*	2.47	0.35	2.12	13.1	12.6	1	7.21	6.61
ARECACEAE	*Euterpe edulis*	1.52	0.48	0.28	11	10.50	1	10.45	7.15
MYRTACEAE	*Eugenia pyriformis*	10.29	2.38	7.91	30.10	28.52	1.5	14.65	11.57

Appendix II

GLMMs for SIP models

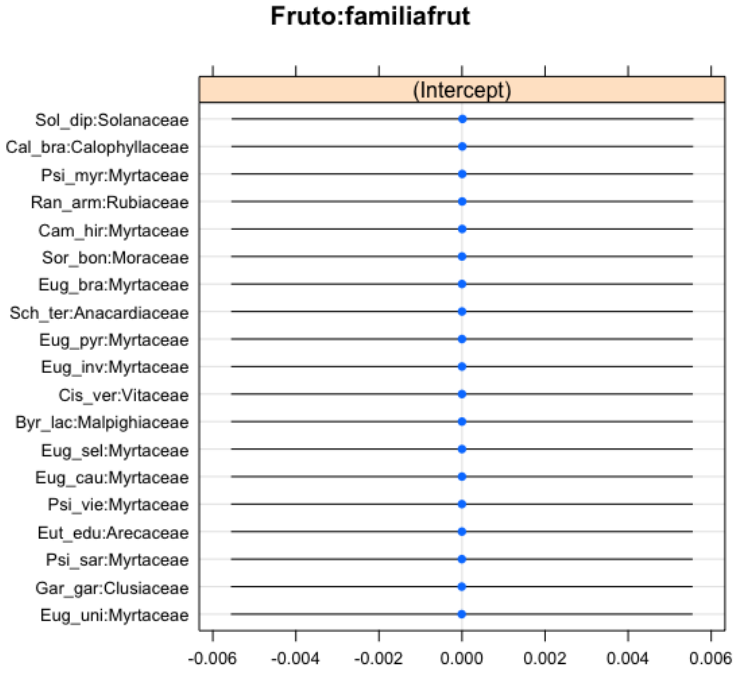
Pseudo-R-squared for Generalized Mixed-Effect models (from MuMin package in R Studio) for the more parsimonious models (Including the Random and fixed variables)

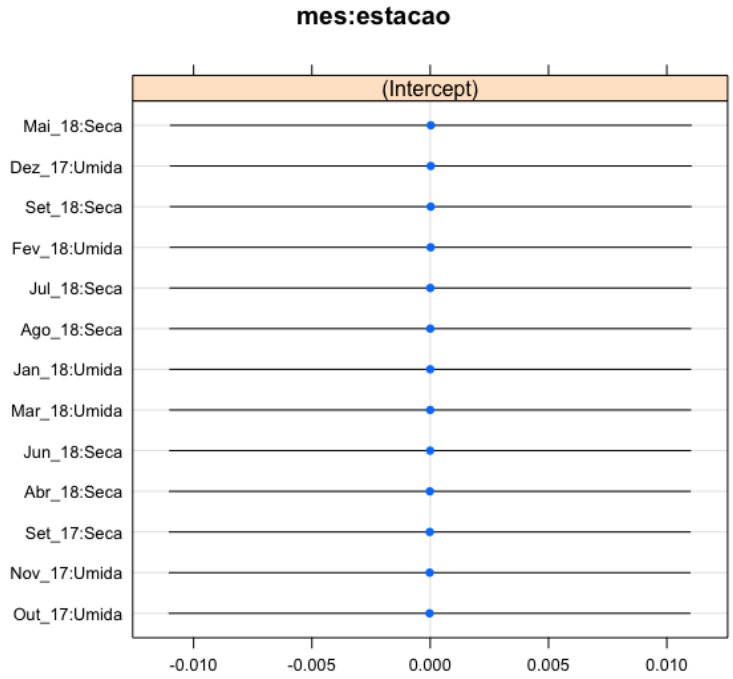
Specie	**Fixed variables**	**Random variables**	**R^2 M DELTA**	**R^2 C DELTA**
Turdus leucomelas	Fruit diameter; Seed diameter	Season; Month; Fruit family, Fruit Species, Matrix	0.7539138	0.7755189
Sapajus nigritus	Seed mass	Season; Month; Fruit family, Fruit Species, Matrix	9.213546e-14	1.511829e-12
Penelope obscura	Fruit abundance	Season; Month; Fruit family, Fruit Species, Matrix	0.04752182	0.9874352
Pitangus sulphuratus	Fruit abundance	Season; Month; Fruit family, Fruit Species, Matrix	0.6545121	0.6545121
Salvator merianae	NONE	Season; Month; Fruit family, Fruit Species, Matrix	0.00	2.196576e-14
Didelphis albiventris	NONE	Season; Month; Fruit family, Fruit Species, Matrix	0.00	0.00
Saltator similis	NONE	Season; Month; Fruit family, Fruit Species, Matrix	0.00	0.7599976
ALL TAXA	Fruit abundance	Season; Month; Fruit family, Fruit Species, Matrix	0.02277227	0.3037486
BIRDS	Fruit abundance	Season; Month; Fruit family, Fruit Species, Matrix	0.01718659	0.5431012
MAMMALS	Fruit abundance	Season; Month; Fruit family, Fruit Species, Matrix	0.06160047	0.2310045

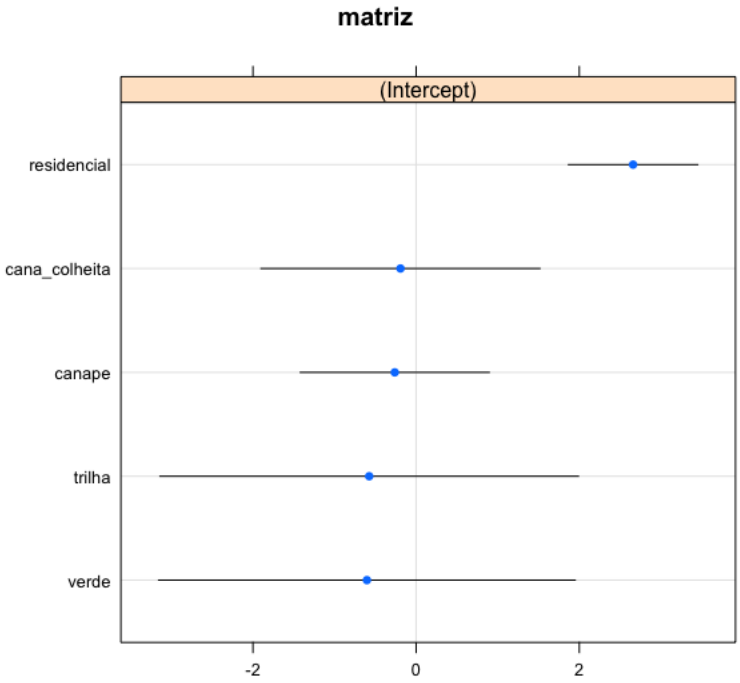
GLMMs for fruit attributes

Common Bivariate Trellis Plots (From package Lattice)
Dotplot for each random variable after selection of the more parsimonious models and their respective Summary (function SUMMARY)

Turdus leucomelas



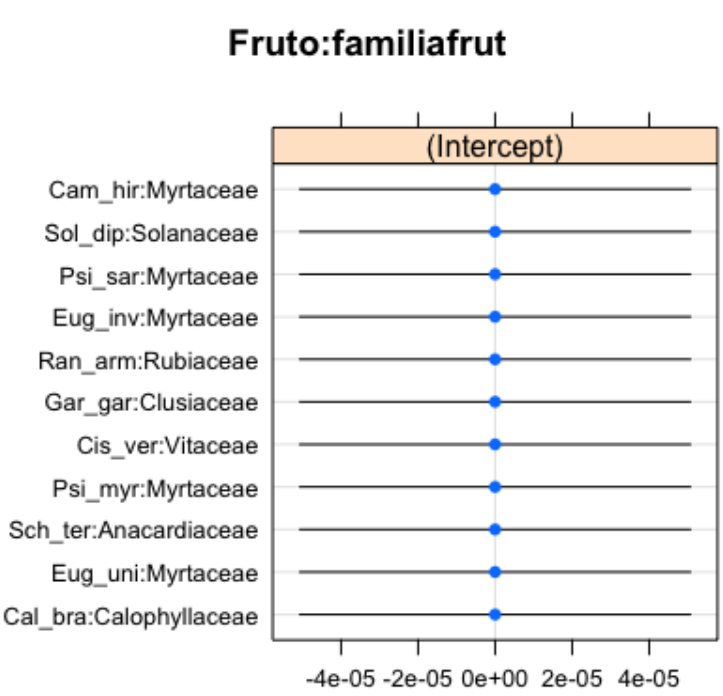


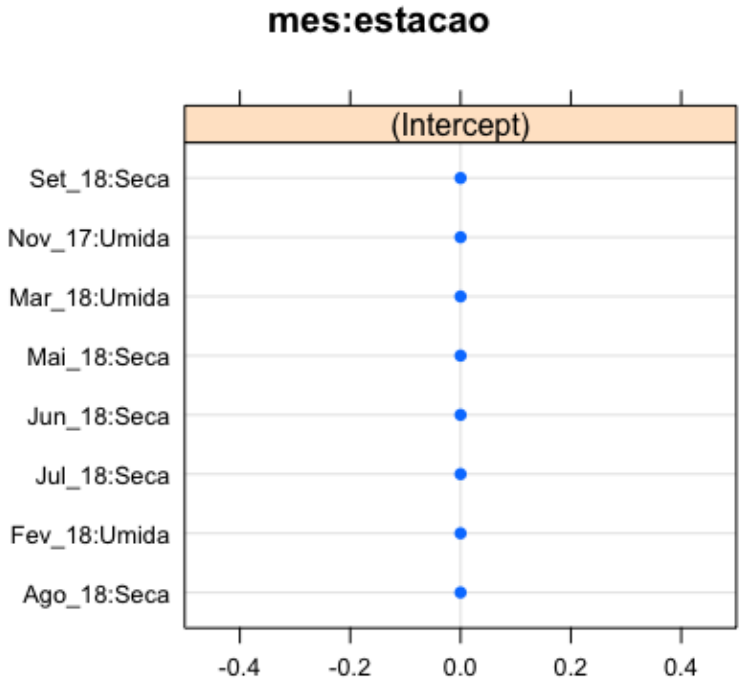


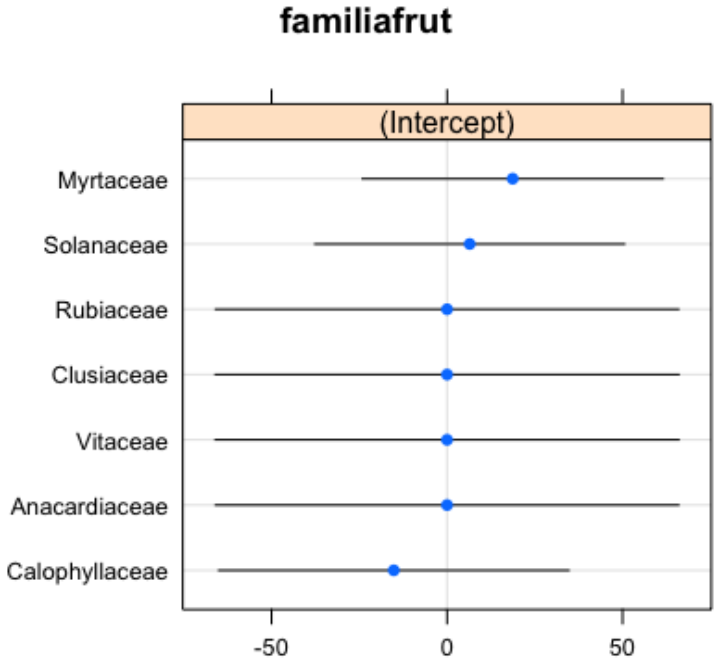

```
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: propingeridos ~ diamfrutomen + diamsemmaior + (1 | estacao/mes)
+
    (1 | familiafrut/Fruto) + (1 | matriz)
   Data: turdus

     AIC      BIC   logLik deviance df.resid
   103.6    124.5    -43.8     87.6       93
```

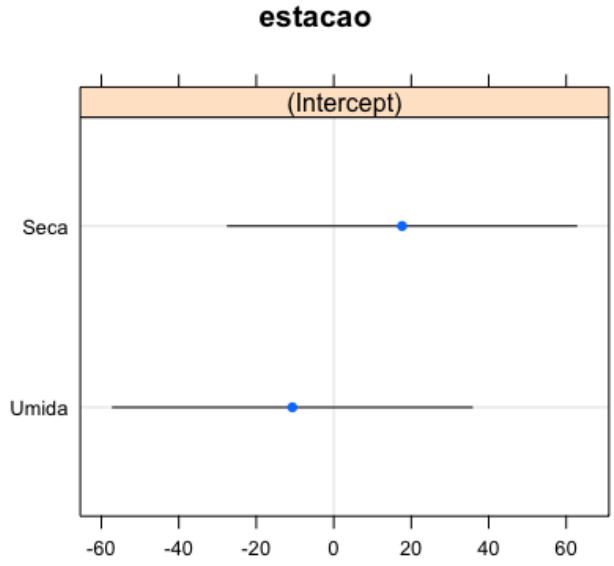
```
Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.9592 -0.3526 -0.0122  0.5398  2.2264

Random effects:
 Groups            Name        Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 0.000e+00 0.000e+00
 mes:estacao       (Intercept) 0.000e+00 0.000e+00
 familiafrut       (Intercept) 2.488e-10 1.577e-05
 matriz            (Intercept) 3.920e-01 6.261e-01
 estacao           (Intercept) 0.000e+00 0.000e+00
Number of obs: 101, groups:
Fruto:familiafrut,  14;  mes:estacao,  10;  familiafrut,  7;  matriz,  5;
estacao, 2

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)    1.1193     0.8122   1.378  0.16818
diamfrutomen  -0.5957     0.1900  -3.136  0.00171 **
diamsemmaior   0.5523     0.2326   2.375  0.01757 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

- ***Sapajus nigritus***







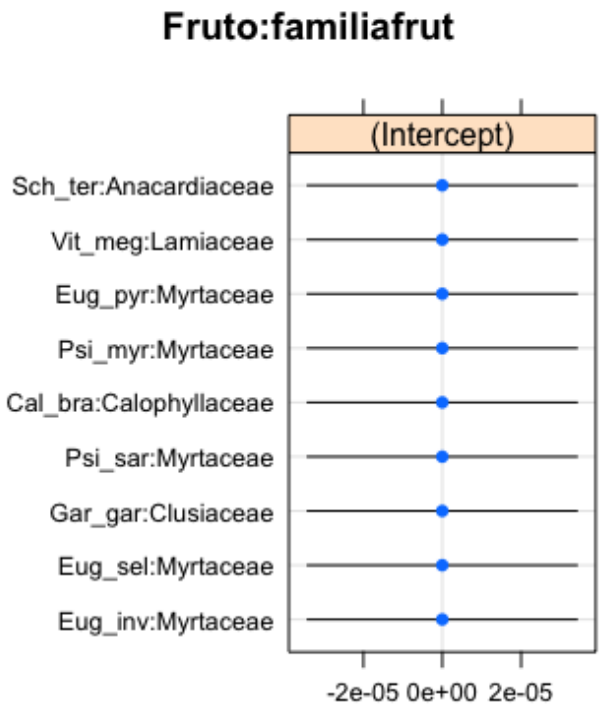


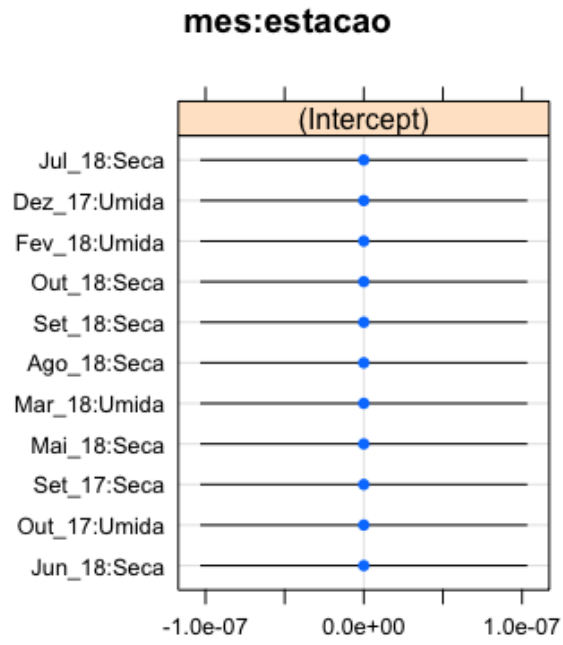
```
> summary(B4)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: propingeridos ~ msemente + +(1 | estacao/mes) + (1 | familiafrut/Fruto) +
    (1 | matriz)
   Data: sapajus

     AIC      BIC   logLik deviance df.resid
    39.1     52.0    -12.5     25.1       40

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.42132  0.00000  0.00003  0.03078  0.70357

Random effects:
 Groups           Name        Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 6.681e-10 2.585e-05
 mes:estacao      (Intercept) 0.000e+00 0.000e+00
 familiafrut      (Intercept) 1.135e+03 3.369e+01
 matriz           (Intercept) 4.466e+03 6.683e+01
 estacao          (Intercept) 7.929e+02 2.816e+01
Number of obs: 47, groups:
Fruto:familiafrut, 11; mes:estacao, 8; familiafrut, 7; matriz, 3; estacao, 2

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -71.405     18.821  -3.794 0.000148 ***
msemente      38.656      9.556   4.045 5.22e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
        (Intr)
msemente -0.852
```

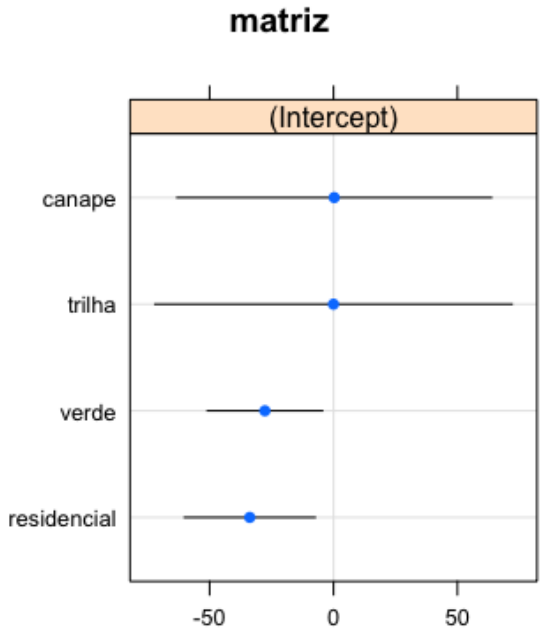
convergence code: 0

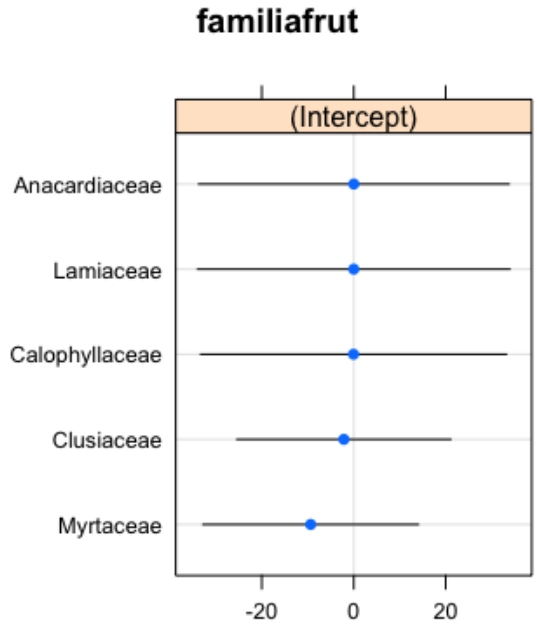
boundary (singular) fit: see ?isSingular

- ***Penelope obscura***









```
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: propingeridos ~ diamfrutomen + Frutosencontrados + (1 | estacao/mes) +
   (1 | familiafrut/Fruto) + (1 | matriz)
  Data: penelope

    AIC      BIC   logLik deviance df.resid
   37.0     47.0    -10.5     21.0       18

Scaled residuals:
    Min      1Q  Median      3Q     Max
-0.60230 -0.13509 -0.00286  0.00073  2.47281

Random effects:
 Groups          Name        Variance  Std.Dev.
 mes:estacao     (Intercept) 2.750e-15 5.244e-08
 Fruto:familiafrut (Intercept) 3.032e-10 1.741e-05
 familiafrut     (Intercept) 3.004e+02 1.733e+01
 matriz          (Intercept) 1.592e+03 3.990e+01
 estacao         (Intercept) 5.599e-11 7.483e-06
Number of obs: 26, groups:  mes:estacao, 11; Fruto:familiafrut, 9; familiafrut, 5; matriz, 4; estacao, 2

Fixed effects:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)       68.3368    29.3038   2.332   0.0197 *
diamfrutomen      -1.2195     0.7257  -1.681   0.0928 .
Frutosencontrados  -0.7967     0.3436  -2.319   0.0204 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr) dmfrtm
```

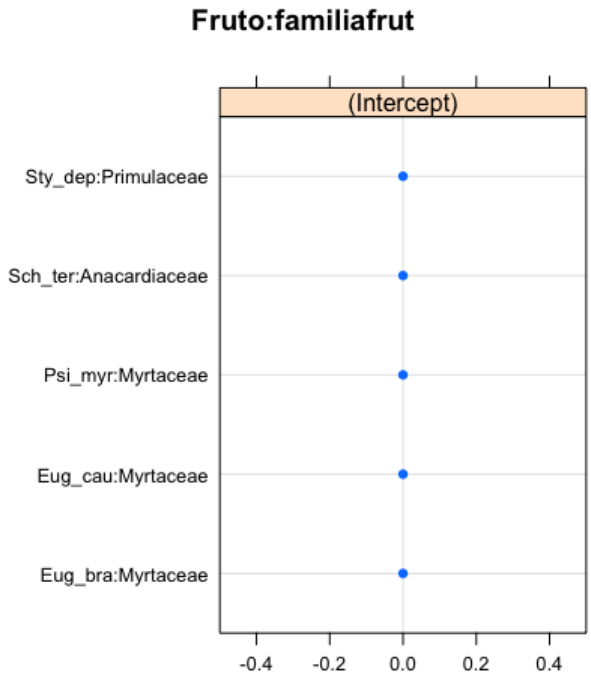
diamfrutomn -0.808

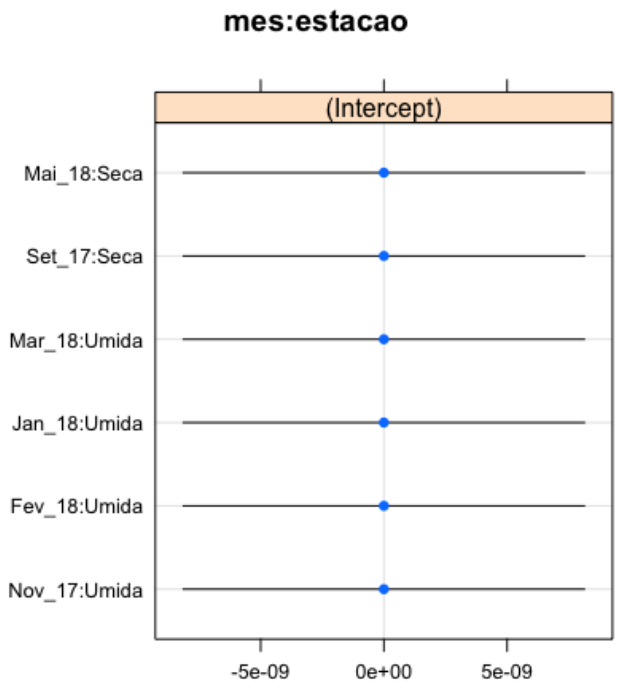
Frtsncntrds -0.973 0.706

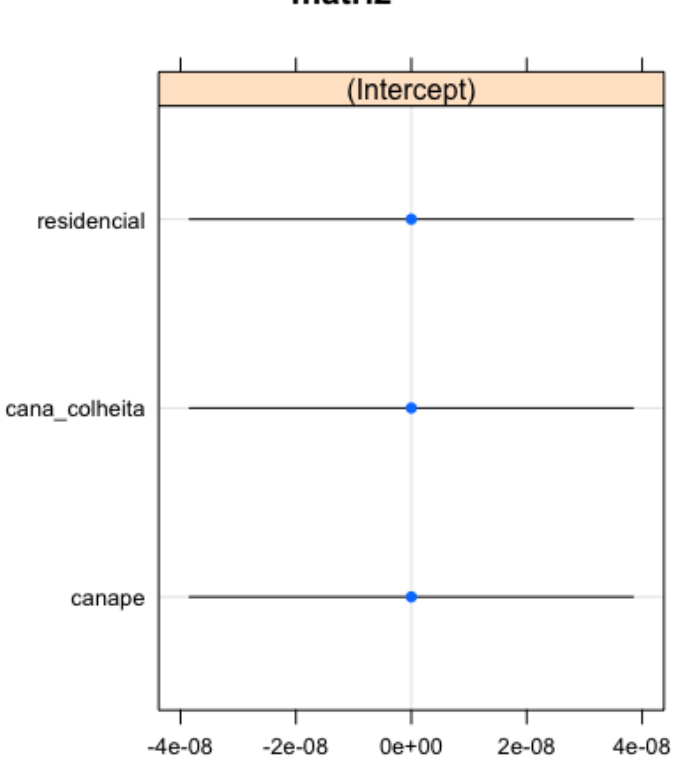
convergence code: 0

boundary (singular) fit: see ?isSingular

- ***Pitangus sulphuratus***







```
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: propingeridos ~ Frutosencontrados + (1 | estacao/mes) + (1 |
familiafrut/Fruto) + (1 | matriz)
   Data: pitangus

     AIC      BIC   logLik deviance df.resid
    24.6     30.4     -5.3     10.6       10

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.1655 -0.4047  0.1154  0.1821  3.4939

Random effects:
 Groups            Name        Variance  Std.Dev.
 mes:estacao       (Intercept) 1.723e-17 4.151e-09
 Fruto:familiafrut (Intercept) 0.000e+00 0.000e+00
 matriz            (Intercept) 3.840e-16 1.960e-08
 familiafrut       (Intercept) 0.000e+00 0.000e+00
 estacao           (Intercept) 0.000e+00 0.000e+00
Number of obs: 17, groups:  mes:estacao, 6; Fruto:familiafrut, 5; matriz,
3; familiafrut, 3; estacao, 2

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       -3.26795    1.48033  -2.208   0.0273 *
Frutosencontrados  0.03647    0.01620   2.251   0.0244 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr)
Frtsncntrds -0.844
convergence code: 0
boundary (singular) fit: see ?isSingular
```

- ***Salvator merianae***

```
> summary(B3)
```

```
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: propingeridos ~ diamfrutomen + (1 | estacao/mes) + (1 |
familiafrut/Fruto) +      (1 | matriz)
   Data: salvator

     AIC      BIC   logLik deviance df.resid
    49.8     60.3    -17.9     35.8       26

Scaled residuals:
     Min       1Q   Median       3Q      Max
-1.42576 -0.17785 -0.06645  0.33929  0.71424

Random effects:
 Groups            Name        Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 1.081e+01 3.28858
 mes:estacao       (Intercept) 1.210e+01 3.47828
 matriz            (Intercept) 1.469e+00 1.21205
 familiafrut       (Intercept) 4.752e-06 0.00218
 estacao           (Intercept) 0.000e+00 0.00000
Number of obs: 33, groups:  Fruto:familiafrut, 12; mes:estacao, 9;
matriz, 4; familiafrut, 4; estacao, 2

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)    2.2990     4.7163   0.487    0.626
diamfrutomen  -0.2939     0.2641  -1.113    0.266
```

- ***Didelphis albiventris***

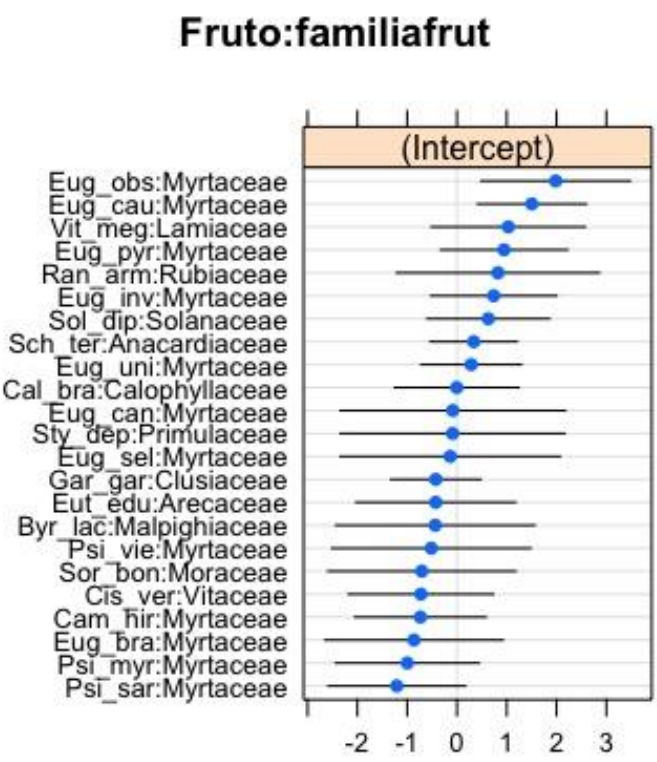
```
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: propingeridos ~ nosementes + (1 | estacao/mes) + (1 |
familiafrut/Fruto) +      (1 | matriz)
   Data: d1

     AIC      BIC   logLik deviance df.resid
    34.5     56.9    -10.3     20.5      174

Scaled residuals:
    Min      1Q  Median      3Q     Max
-0.3440 -0.0871 -0.0866 -0.0866 11.5506

Random effects:
 Groups            Name        Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 1.171e-15 3.422e-08
 mes:estacao       (Intercept) 3.262e-15 5.711e-08
 familiafrut       (Intercept) 0.000e+00 0.000e+00
 matriz            (Intercept) 0.000e+00 0.000e+00
 estacao           (Intercept) 0.000e+00 0.000e+00
Number of obs: 181, groups:  Fruto:familiafrut, 17; mes:estacao, 13;
familiafrut, 8; matriz, 4; estacao, 2
```

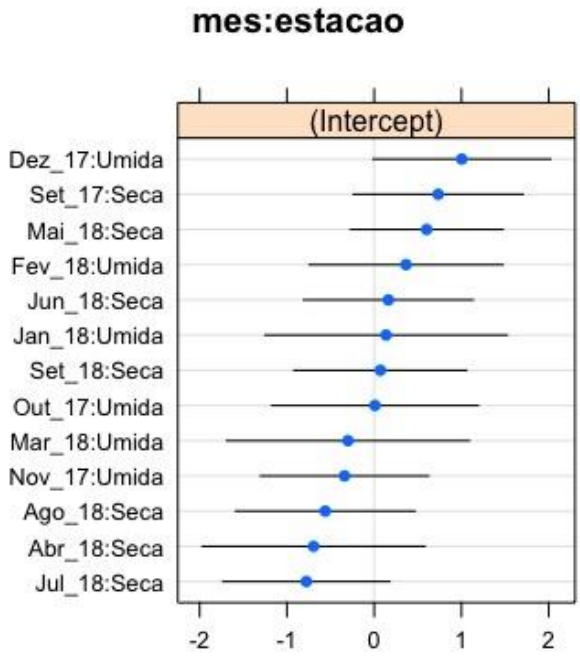
```
Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -4.907801   0.889940  -5.515 3.49e-08 ***
nosementes   0.014333   0.009985   1.435    0.151
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
           (Intr)
nosementes -0.592
convergence code: 0
boundary (singular) fit: see ?isSingular
```

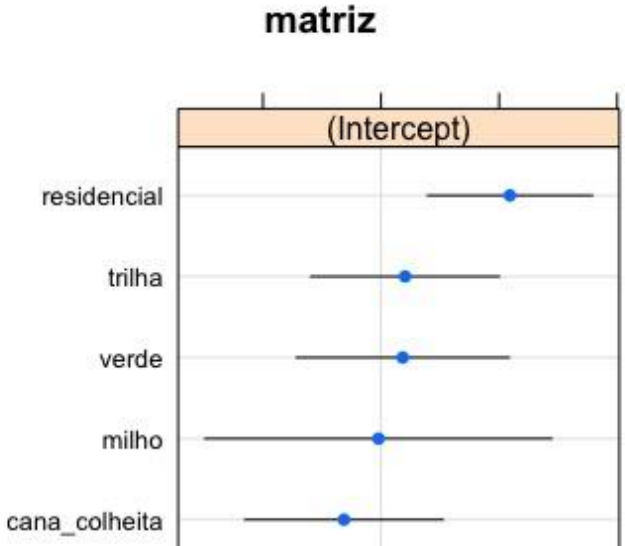
- ***Saltator similis***

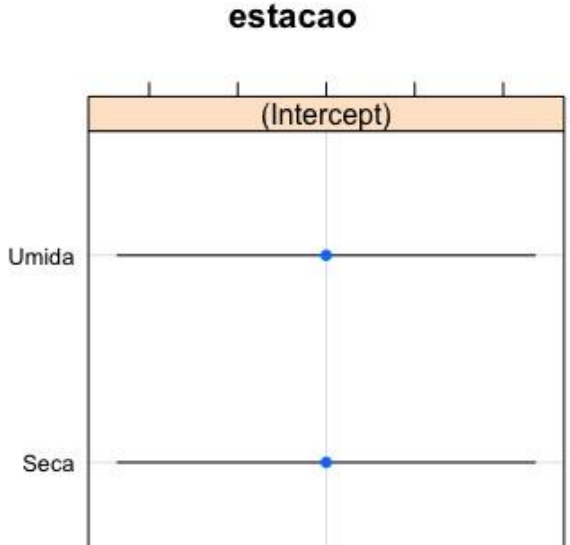
```
Family: binomial  ( logit )
Formula: propingeridos ~ (1 | estacao/mes) + (1 | familiafrut/Fruto)
+      (1 | matriz)
   Data: SM

     AIC      BIC   logLik deviance df.resid
    33.2     39.2    -10.6     21.2       14

Scaled residuals:
     Min       1Q   Median       3Q      Max
-0.85691 -0.85691 -0.08484  0.23451  1.16698

Random effects:
 Groups            Name        Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 1.322e+01 3.637e+00
 mes:estacao       (Intercept) 1.886e-09 4.343e-05
 matriz            (Intercept) 1.870e-10 1.368e-05
 familiafrut       (Intercept) 0.000e+00 0.000e+00
 estacao           (Intercept) 0.000e+00 0.000e+00
Number of obs: 20, groups:  Fruto:familiafrut, 7; mes:estacao, 7;
matriz, 3; familiafrut, 3; estacao, 2

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)   -4.840      6.755  -0.716    0.474
convergence code: 0
boundary (singular) fit: see ?isSingular
```

- **All taxa**


Fruto:familiafrut
(Intercept)
Eug_obs:Myrtaceae
Eug_cau:Myrtaceae
Vit_meg:Lamiaceae
Eug_pyr:Myrtaceae
Ran_arm:Rubiaceae
Eug_inv:Myrtaceae
Sol_dip:Solanaceae
Sch_ter:Anacardiaceae
Eug_uni:Myrtaceae
Cal_bra:Calophyllaceae
Eug_can:Myrtaceae
Sty_dep:Primulaceae
Eug_sel:Myrtaceae
Gar_gar:Clusiaceae
Eut_edu:Arecaceae
Byr_lac:Malpighiaceae
Psi_vie:Myrtaceae
Sor_bon:Moraceae
Cis_ver:Vitaceae
Cam_fir:Myrtaceae
Eug_bra:Myrtaceae
Psi_myr:Myrtaceae
Psi_sar:Myrtaceae
-2 -1 0 1 2 3


mes:estacao
(Intercept)
Dez_17:Umida
Set_17:Seca
Mai_18:Seca
Fev_18:Umida
Jun_18:Seca
Jan_18:Umida
Set_18:Seca
Out_17:Umida
Mar_18:Umida
Nov_17:Umida
Ago_18:Seca
Abr_18:Seca
Jul_18:Seca
-2 -1 0 1 2

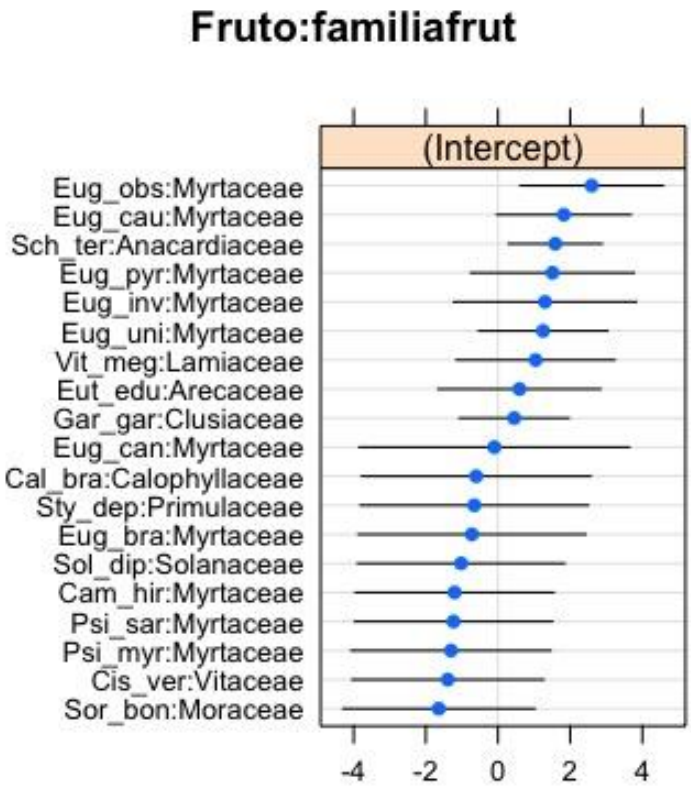

matriz
(Intercept)
residencial
trilha
verde
milho
cana_colheita

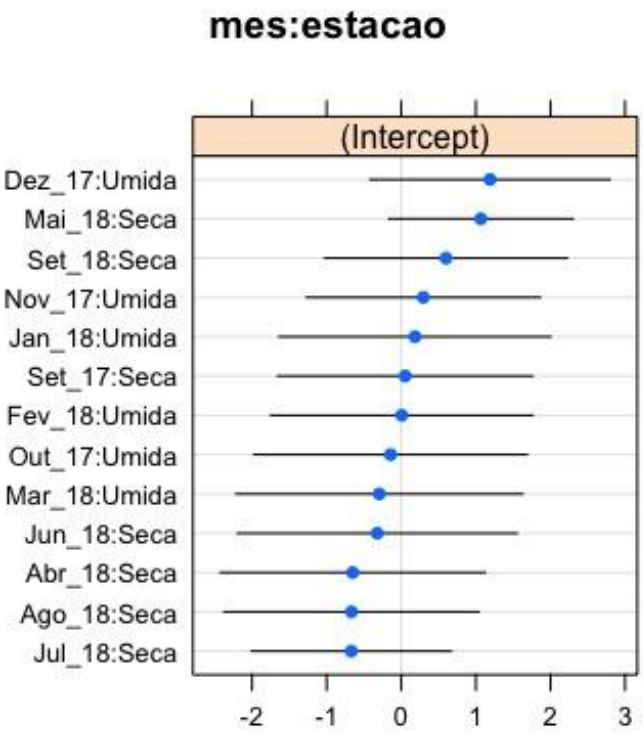

estacao
(Intercept)
Umida
Seca

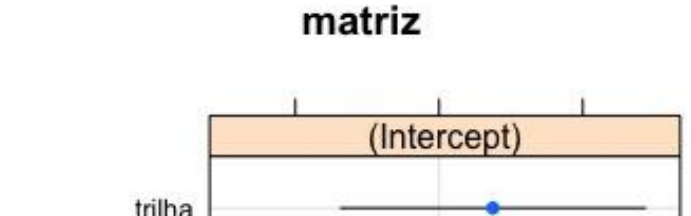
```
> summary(B1)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
 Family: binomial  ( logit )
Formula: propingeridos ~ Frutosencontrados + +(1 | estacao/mes) + (1 |
    familiafrut/Fruto) + (1 | matriz)
   Data: geral

     AIC      BIC   logLik deviance df.resid
   460.7    491.5   -223.4    446.7      592

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.4880 -0.3728 -0.2277 -0.1551  5.8858

Random effects:
 Groups           Name        Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 1.432e+00 1.197e+00
 mes:estacao       (Intercept) 6.248e-01 7.905e-01
 familiafrut       (Intercept) 1.463e-10 1.210e-05
 matriz            (Intercept) 5.720e-01 7.563e-01
 estacao           (Intercept) 1.447e-10 1.203e-05
Number of obs: 599, groups:  Fruto:familiafrut, 23; mes:estacao, 13; familiafrut, 12; matriz, 6;
estacao, 2

Fixed effects:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)      -2.512998   0.568344  -4.422  9.8e-06 ***
Frutosencontrados  0.013048   0.004502   2.899  0.00375 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Correlation of Fixed Effects:
(Intr)
Frtsncntrds -0.338
convergence code: 0
boundary (singular) fit: see ?isSingular

Birds







```
> summary(B2)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation)
['glmerMod']
 Family: binomial  ( logit )
Formula: propingeridos ~ Frutosencontrados + (1 | estacao/mes) + (1 |      familiafrut/Fruto)
+ (1 | matriz)
   Data: birds

     AIC      BIC   logLik deviance df.resid
   246.2    271.8   -116.1    232.2      280

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.7032 -0.3694 -0.1852 -0.0865  4.8867

Random effects:
 Groups           Name        Variance Std.Dev.
 Fruto:familiafrut (Intercept) 3.99119  1.9978
 mes:estacao       (Intercept) 1.13747  1.0665
 familiafrut       (Intercept) 0.00000  0.0000
```

matriz (Intercept) 0.09838 0.3137
estacao (Intercept) 0.74434 0.8628
Number of obs: 287, groups: Fruto:familiafrut, 19; mes:estacao, 13; familiafrut, 10; matriz, 6; estacao, 2

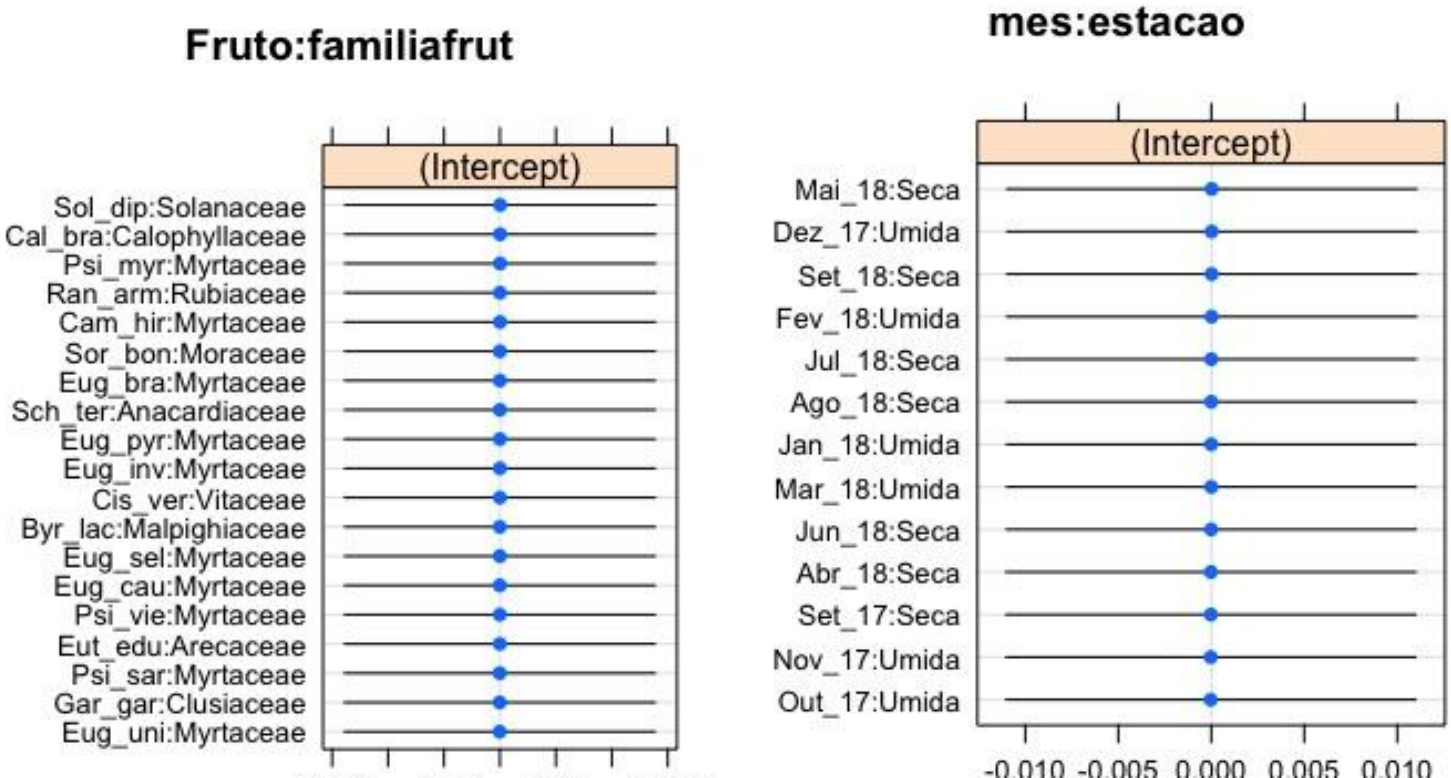
Fixed effects:

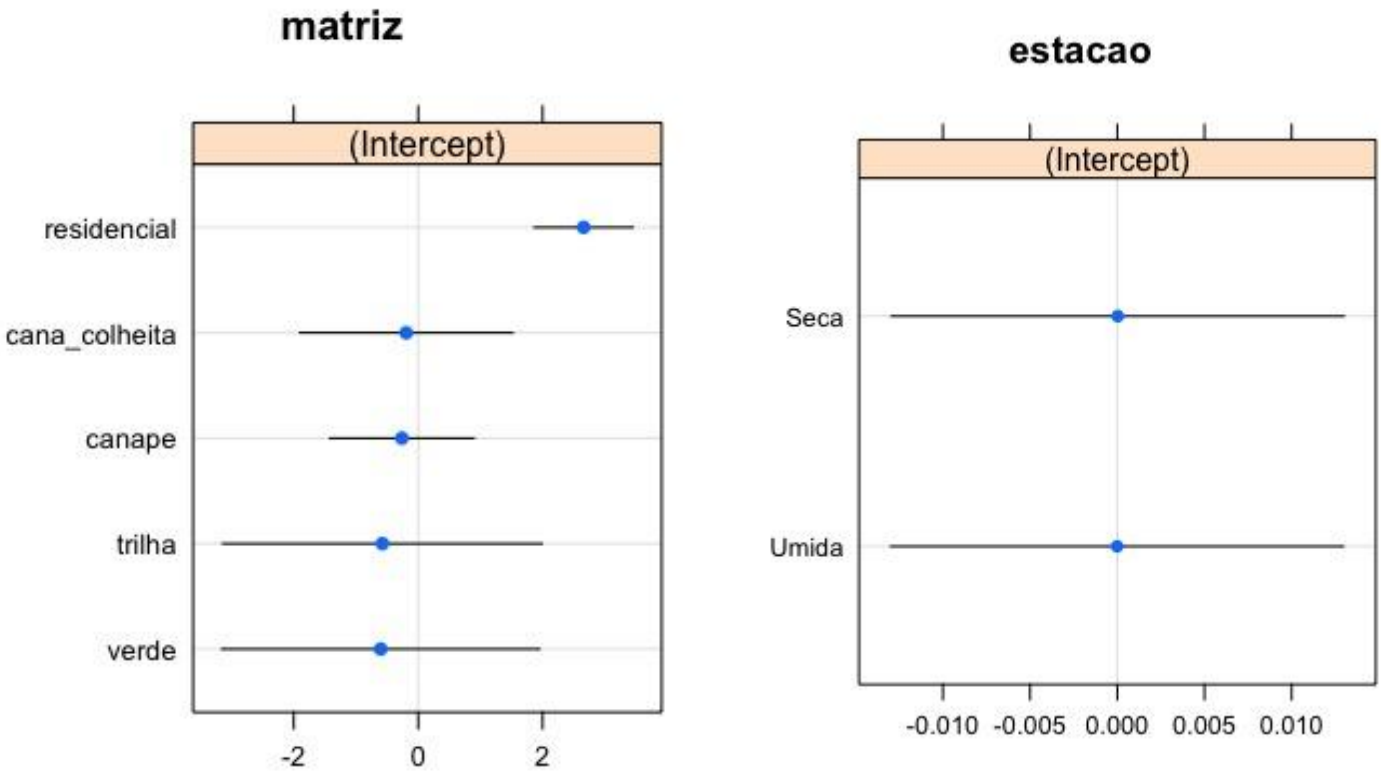
	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.908178	1.056621	-2.752	0.00592	**
Frutosencontrados	0.009840	0.004992	1.971	0.04870	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
(Intr)
Frtsncntrds -0.197
convergence code: 0
boundary (singular) fit: see ?isSingular

- **Mammals**





> summary(B3)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
Family: binomial (logit)
Formula: propingeridos ~ Frutosencontrados + (1 | estacao/mes) + (1 | familiafrut/Fruto) + (1 | matriz)
Data: ma

AIC	BIC	logLik	deviance	df.resid
113.9	139.6	-49.9	99.9	286

Scaled residuals:

Min	1Q	Median	3Q	Max
-0.7672	-0.1855	-0.1284	-0.0722	24.6248

Random effects:

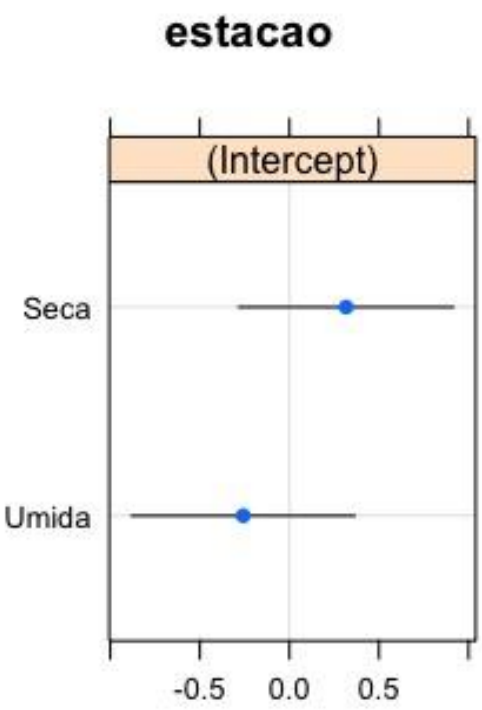
```
 Groups          Name       Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 7.997e-06 0.002828
 mes:estacao       (Intercept) 3.151e-05 0.005613
 familiafrut       (Intercept) 2.236e-01 0.472862
 matriz            (Intercept) 2.669e+00 1.633617
 estacao           (Intercept) 4.388e-05 0.006624
Number of obs: 293, groups:  Fruto:familiafrut, 19; mes:estacao, 13; familiafrut, 10; matriz,
5; estacao, 2

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)      -2.42633    1.08620  -2.234   0.0255 *
Frutosencontrados -0.04603    0.01990  -2.313   0.0207 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
        (Intr)
Frtsncntrds -0.328
convergence code: 0
Model failed to converge with max|grad| = 0.0209198 (tol = 0.001, component 1)
```

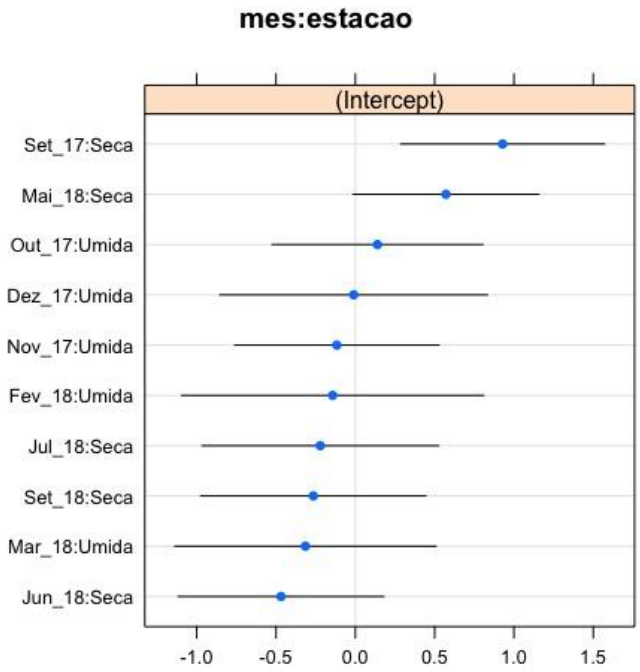
- **GLMMs for Space-use Pattern**

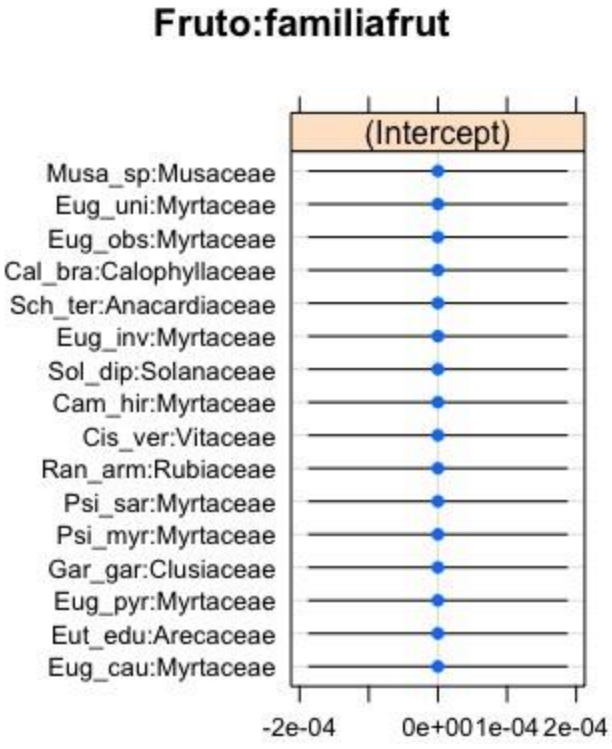
Turdus leucomelas

```
> summary(B4)
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: poisson  ( log )
Formula: visitas ~ matriz + (1 | estacao/mes) + (1 | familiafrut/Fruto) +
(1 | hvisita)
   Data: t3

     AIC      BIC   logLik deviance df.resid
   291.6    312.6   -135.8    271.6       50
```

```
Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.8545 -0.7285 -0.2861  0.4045  2.9343

Random effects:
 Groups            Name        Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 9.027e-09 9.501e-05
 mes:estacao       (Intercept) 3.165e-01 5.626e-01
 familiafrut       (Intercept) 6.856e-01 8.280e-01
 hvisita           (Intercept) 3.003e-01 5.480e-01
 estacao           (Intercept) 1.836e-01 4.284e-01
Number of obs: 60, groups:  Fruto:familiafrut, 16; mes:estacao, 10;
familiafrut, 9; hvisita, 4; estacao, 2

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       -0.40006    0.65276  -0.613 0.539957
matrizcanape       0.95763    0.45207   2.118 0.034149 *
matrizresidencial  1.00060    0.26210   3.818 0.000135 ***
matriztrilha      -0.06727    0.37758  -0.178 0.858598
matrizverde        0.46369    0.53528   0.866 0.386354
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> Anova(B4, type = "III")
Analysis of Deviance Table (Type III Wald chisquare tests)

Response: visitas
             Chisq Df Pr(>Chisq)
(Intercept)  0.3756  1   0.539957
matriz      20.1759  4   0.000461 ***
```


estacao
(Intercept)
Seca
Umida
-0.5
0.0
0.5

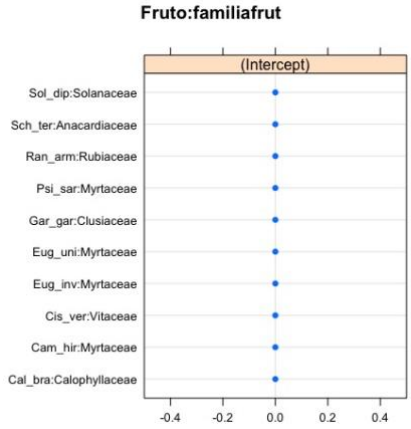

mes:estacao
(Intercept)
Set_17:Seca
Mai_18:Seca
Out_17:Umida
Dez_17:Umida
Nov_17:Umida
Fev_18:Umida
Jul_18:Seca
Set_18:Seca
Mar_18:Umida
Jun_18:Seca
-1.0
-0.5
0.0
0.5
1.0
1.5

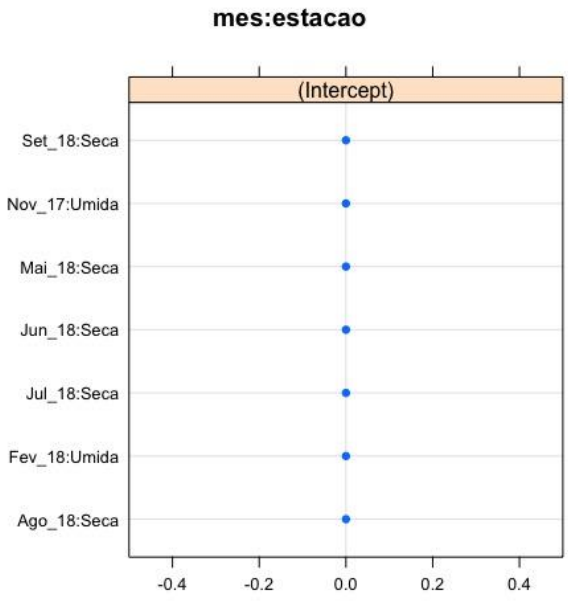

Fruto:familiafrut
(Intercept)
Musa_sp:Musaceae
Eug_uni:Myrtaceae
Eug_obs:Myrtaceae
Cal_bra:Calophyllaceae
Sch_ter:Anacardiaceae
Eug_inv:Myrtaceae
Sol_dip:Solanaceae
Cam_hir:Myrtaceae
Cis_ver:Vitaceae
Ran_arm:Rubiaceae
Psi_sar:Myrtaceae
Psi_myr:Myrtaceae
Gar_gar:Clusiaceae
Eug_pyr:Myrtaceae
Eut_edu:Arecaceae
Eug_cau:Myrtaceae
-2e-04
0e+00
1e-04
2e-04

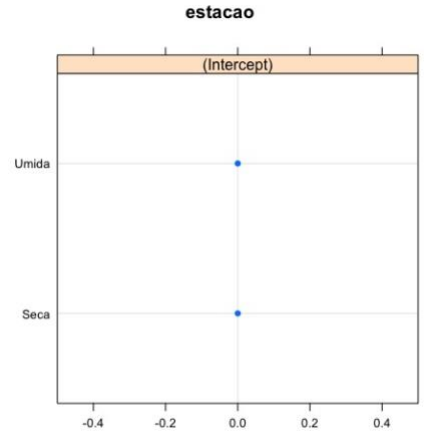
Sapajus nigritus

```
> summary(B3)
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: poisson  ( log )
Formula: visitas ~ conservacao + (1 | estacao/mes) + (1 |
familiafrut/Fruto)
   Data: s2

     AIC      BIC   logLik deviance df.resid
    57.4     62.4    -22.7     45.4       11

Scaled residuals:
    Min      1Q  Median      3Q     Max
-0.6621 -0.6621 -0.6325  0.7825  2.2271

Random effects:
 Groups            Name        Variance Std.Dev.
 Fruto:familiafrut (Intercept) 0        0
 familiafrut       (Intercept) 0        0
 mes:estacao       (Intercept) 0        0
 estacao           (Intercept) 0        0
Number of obs: 17, groups:  Fruto:familiafrut, 10; familiafrut, 7;
mes:estacao, 7; estacao, 2

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)    0.6506     0.2085   3.120  0.00181 **
conservacaoVS -1.5669     0.7372  -2.125  0.03355 *
```

Dotplot (ICC test)

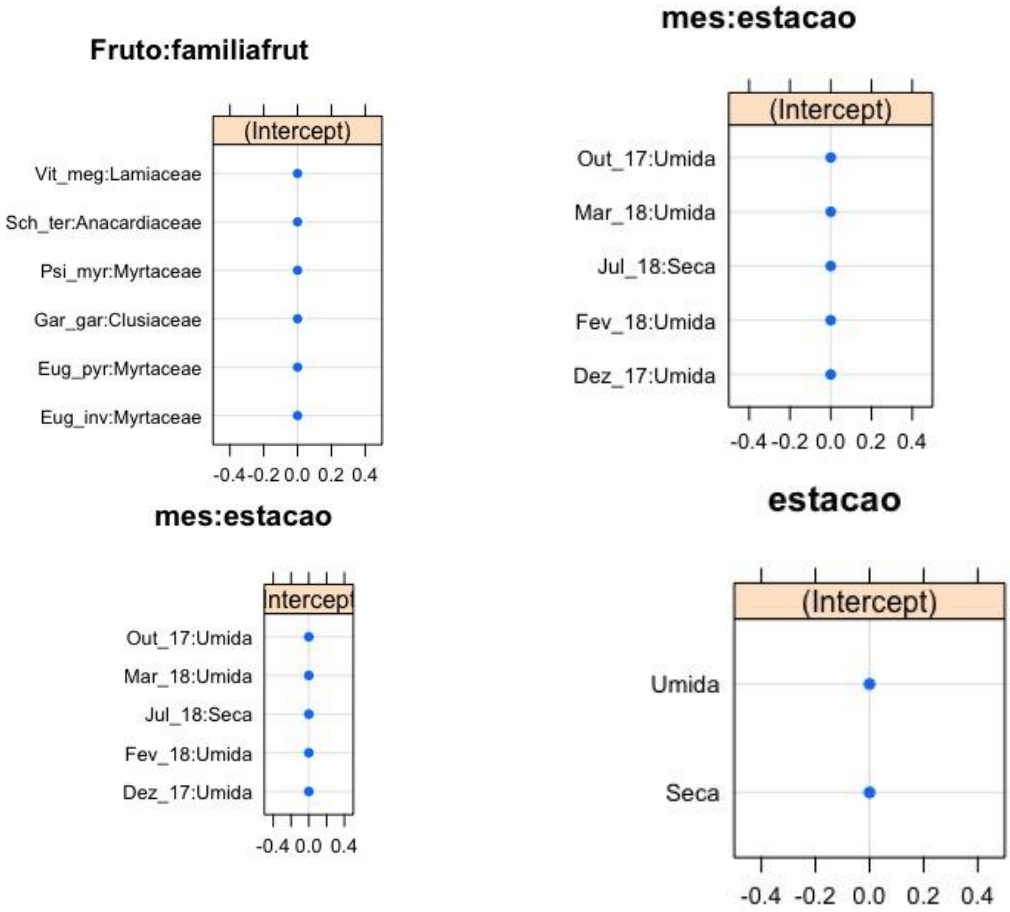






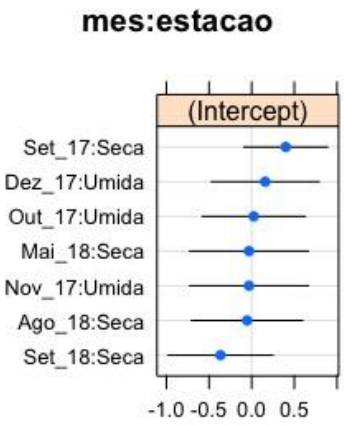
Didelphis albiventris

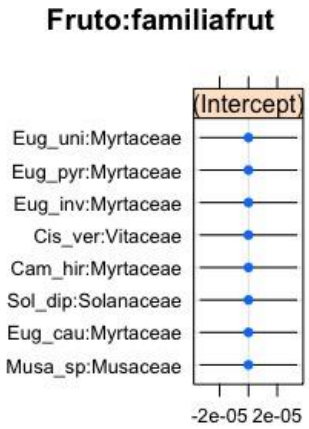
```
> summary(B4)
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: poisson  ( log )
Formula: visitas ~ posicaodoponto + (1 | estacao/mes) + (1 |
familiafrut/Fruto)
   Data: d2

     AIC      BIC   logLik deviance df.resid
    51.2     57.8    -19.6     39.2       16

Scaled residuals:
    Min      1Q  Median      3Q     Max
-0.4472  0.0000  0.0000  0.0000  1.7889

Random effects:
 Groups            Name        Variance Std.Dev.
 Fruto:familiafrut (Intercept) 0        0
 mes:estacao       (Intercept) 0        0
 familiafrut       (Intercept) 0        0
 estacao           (Intercept) 0        0
Number of obs: 22, groups:  Fruto:familiafrut, 6; mes:estacao, 5;
familiafrut, 4; estacao, 2

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)         -1.609      1.000  -1.609    0.108
posicaodopontolow    1.609      1.029   1.564    0.118
```

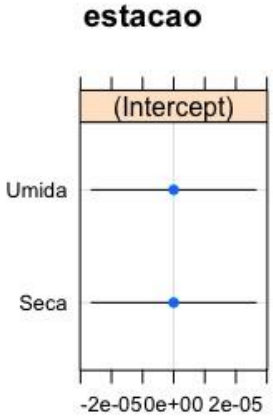

Fruto:familiafrut
(Intercept)
Vit_meg:Lamiaceae
Sch_ter:Anacardiaceae
Psi_myr:Myrtaceae
Gar_gar:Clusiaceae
Eug_pyr:Myrtaceae
Eug_inv:Myrtaceae
-0.4 -0.2 0.0 0.2 0.4
mes:estacao
(Intercept)
Out_17:Umida
Mar_18:Umida
Jul_18:Seca
Fev_18:Umida
Dez_17:Umida
-0.4 -0.2 0.0 0.2 0.4
mes:estacao
Intercept
Out_17:Umida
Mar_18:Umida
Jul_18:Seca
Fev_18:Umida
Dez_17:Umida
-0.4 0.0 0.4
estacao
(Intercept)
Umida
Seca
-0.4 -0.2 0.0 0.2 0.4

Salvator merianae

```
> summary(S4)
Generalized linear mixed model fit by maximum likelihood (Laplace
Approximation) ['glmerMod']
 Family: poisson  ( log )
Formula: visitas ~ 1 + (1 | estacao/mes) + (1 | familiafrut/Fruto)
   Data: s3

     AIC      BIC   logLik deviance df.resid
    63.4     67.8    -26.7     53.4       13

Scaled residuals:
     Min       1Q   Median       3Q      Max
-0.93072 -0.63124 -0.21881  0.06581  2.30077

Random effects:
 Groups             Name        Variance  Std.Dev.
 Fruto:familiafrut (Intercept) 2.885e-10 1.699e-05
 mes:estacao       (Intercept) 1.482e-01 3.850e-01
 familiafrut       (Intercept) 0.000e+00 0.000e+00
 estacao           (Intercept) 1.817e-10 1.348e-05
Number of obs: 18, groups:  Fruto:familiafrut, 8; mes:estacao, 7;
familiafrut, 4; estacao, 2
```







Appendix III

Legal authorizations

TERMO DE COMPROMISSO PARA REALIZAÇÃO DE PESQUISAS CIENTÍFICAS NA ARIE MATA DE SANTA GENEBRA – **PROTOCOLO FJPO Nº**_____ (favor não preencher)

Eu Wesley Rodrigues Silva, portador do CPF 016.042.928-57, pesquisador da instituição Universidade Estadual de Campinas, na qualidade de responsável pelo desenvolvimento do Projeto de Pesquisa intitulado "A fauna frugívora remanescente de um fragmento florestal degradado e seu papel no enriquecimento da vegetação", com prazo de execução previsto de agosto/2017 a julho/2018, **comprometo-me a**:

1. Respeitar a legislação brasileira relacionada à pesquisa científica; bem como toda a legislação brasileira e tratados internacionais de proteção dos recursos naturais;
2. Enviar uma cópia do material fotográfico e de vídeo eventualmente produzidos para a utilização da FJPO em ações educativas e institucionais;
3. Enviar ao Departamento Técnico-Científico da Fundação José Pedro de Oliveira exemplar de produção técnica, científica ou artística, no prazo máximo de 90 (noventa) a partir de sua publicação, produzido como resultado direto ou indireto de pesquisa realizada na Mata de Santa Genebra, incluindo-se artigo científico, livro, tese, dissertação, monografia, tese de conclusão de curso, relatório de iniciação científica, separata, apresentação em congresso, resumo, etc.;
4. Enviar convite para o dia da defesa/apresentação da tese/dissertação/pesquisa à FJPO;
5. Apresentar os resultados da pesquisa à FJPO quando solicitado pela mesma;
6. Executar exclusivamente o previsto no projeto de pesquisa aprovado pela FJPO e comunicar previamente qualquer alteração no projeto, devidamente justificada, para autorização;
7. Informar oficialmente à FJPO desistência ou cancelamento das atividades;
8. Autorizar a FJPO a utilizar as informações geradas por este trabalho em divulgações técnicas, bem como para atividades voltadas para educação ambiental e para conservação;
9. Portar o cartão de autorização de pesquisa, durante os trabalhos de campo, e exibi-lo aos vigilantes ou servidores da FJPO sempre que solicitado;
10. **A retirar, até o final dos trabalhos, todos os materiais utilizados para a coleta de dados, tais como: armadilhas, fitas, placas, plaquetas, baldes, etc;**

Declaro, por fim, que eximo a FJPO de toda e qualquer responsabilidade em decorrência de acidentes e sinistros pessoais e materiais que possam ocorrer comigo ou com minha equipe, no interior da MSG.

Local e data: Campinas, 01 de agosto de 2017

Assinatura do responsável pela pesquisa (orientador):_____

UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE BIOLOGIA, www.ib.unicamp.br
Rua Monteiro Lobato, 255 CEP 13083-862 Campinas-SP,
DIRETORIA FONE:(0XX19)3521-6358

Of. IB 157 /2017

Cidade Universitária "Zeferino Vaz", 20 de julho de 2017

Assunto: Realização de Pesquisa Científica na ARIE Mata de Santa Genebra

Senhora Diretora,

O Instituto de Biologia da UNICAMP, representado por seu diretor associado em exercício MARCELO BROCCHI, vem encaminhar dados referentes ao responsável pela realização da Pesquisa Científica na ARIE Mata de Santa Genebra, intitulada "A fauna frugívora remanescente de um fragmento florestal degradado e seu papel no enriquecimento da vegetação", a ser realizada pelo aluno Eduardo Delgado Britez Rigacci, sob orientação do Prof. Dr. Wesley Rodrigues Silva.

Atenciosamente,

Prof. Dr. Marcelo Brocchi
Diretor Associado
Instituto de Biologia - UNICAMP
Matr. 28684-8

Ilma.Sra.
Sabrina Kelly Batista Martins
Diretoria do Departamento Técnico-Científico
Fundação José Pedro de Oliveira
Rua Mata Atlântica, nº 447 - Bosque de Barão
Barão Geraldo, Campinas, SP
13082-755

Ministério do Meio Ambiente - MMA
Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio
Sistema de Autorização e Informação em Biodiversidade - SISBIO

Autorização para atividades com finalidade científica

Número: 58921-1	Data da Emissão: 06/06/2017 15:35	Data para Revalidação*: 06/07/2018

* De acordo com o art. 28 da IN 03/2014, esta autorização tem prazo de validade equivalente ao previsto no cronograma de atividades do projeto, mas deverá ser revalidada anualmente mediante a apresentação do relatório de atividades a ser enviado por meio do Sisbio no prazo de até 30 dias a contar da data do aniversário de sua emissão.

Dados do titular

Nome: Eduardo Delgado Britez Rigacci	CPF: 418.812.448-22
TItulo do Projeto: A fauna frugívora remanescente de um fragmento florestal degradado e seu papel no enriquecimento da vegetação	
Nome da Instituição : UNIVERSIDADE ESTADUAL DE CAMPINAS	CNPJ: 46.068.425/0001-33

Cronograma de atividades

#	Descrição da atividade	Início (mês/ano)	Fim (mês/ano)
1	Instalação de cevas de alimentação ao redor da mata	06/2017	06/2017
2	Rodizio das cameras-trap conforme explicitado no projeto	06/2017	06/2018
3	Enriquecimento com frutos nativos locais	06/2017	06/2018
4	Análise da fauna frugivora	06/2017	06/2018

Observações e ressalvas

1	As atividades de campo exercidas por pessoa natural ou jurídica estrangeira, em todo o território nacional, que impliquem o deslocamento de recursos humanos e materiais, tendo por objeto coletar dados, materiais, espécimes biológicos e minerais, peças integrantes da cultura nativa e cultura popular, presente e passada, obtidos por meio de recursos e técnicas que se destinem ao estudo, à difusão ou à pesquisa, estão sujeitas a autorização do Ministério de Ciência e Tecnologia.
2	Esta autorização NAO exime o pesquisador titular e os membros de sua equipe da necessidade de obter as anuências previstas em outros instrumentos legais, bem como do consentimento do responsável pela área, pública ou privada, onde será realizada a atividade, inclusive do órgão gestor de terra indígena (FUNAI), da unidade de conservação estadual, distrital ou municipal, ou do proprietário, arrendatário, posseiro ou morador de área dentro dos limites de unidade de conservação federal cujo processo de regularização fundiária encontra-se em curso.
3	Este documento somente poderá ser utilizado para os fins previstos na Instrução Normativa ICMBio n° 03/2014 ou na Instrução Normativa ICMBio n° 10/2010, no que especifica esta Autorização, não podendo ser utilizado para fins comerciais, industriais ou esportivos. O material biológico coletado deverá ser utilizado para atividades científicas ou didáticas no âmbito do ensino superior.
4	O titular de licença ou autorização e os membros da sua equipe deverão optar por métodos de coleta e instrumentos de captura direcionados, sempre que possível, ao grupo taxonômico de interesse, evitando a morte ou dano significativo a outros grupos; e empregar esforço de coleta ou captura que não comprometa a viabilidade de populações do grupo taxonômico de interesse em condição in situ.
5	O titular de autorização ou de licença permanente, assim como os membros de sua equipe, quando da violação da legislação vigente, ou quando da inadequação, omissão ou falsa descrição de informações relevantes que subsidiaram a expedição do ato, poderá, mediante decisão motivada, ter a autorização ou licença suspensa ou revogada pelo ICMBio, nos termos da legislação brasileira em vigor.
6	Este documento não dispensa o cumprimento da legislação que dispõe sobre acesso a componente do patrimônio genético existente no território nacional, na plataforma continental e na zona econômica exclusiva, ou ao conhecimento tradicional associado ao patrimônio genético, para fins de pesquisa científica, bioprospecção e desenvolvimento tecnológico. Veja maiores informações em www.mma.gov.br/cgen.
7	Em caso de pesquisa em UNIDADE DE CONSERVAÇÃO, o pesquisador titular desta autorização deverá contactar a administração da unidade a fim de CONFIRMAR AS DATAS das expedições, as condições para realização das coletas e de uso da infra-estrutura da unidade.

Locais onde as atividades de campo serão executadas

#	Município	UF	Descrição do local	Tipo
1		SP	ÁREA DE RELEVANTE INTERESSE ECOLÓGICO MATA DE SANTA GENEBRA	UC Federal

Destino do material biológico coletado

#	Nome local destino	Tipo Destino
1	UNIVERSIDADE ESTADUAL DE CAMPINAS	

Este documento (Autorização para atividades com finalidade científica) foi expedido com base na Instrução Normativa nº 03/2014. Através do código de autenticação abaixo, qualquer cidadão poderá verificar a autenticidade ou regularidade deste documento, por meio da página do Sisbio/ICMBio na Internet (www.icmbio.gov.br/sisbio).

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Sistema de Autorização e Informação em Biodiversidade - SISBIO

Autorização para atividades com finalidade científica

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Dados do titular

Nome: Eduardo Delgado Britez Rigacci	CPF: 418.812.448-22
Título do Projeto: A fauna frugívora remanescente de um fragmento florestal degradado e seu papel no enriquecimento da vegetação	
Nome da Instituição : UNIVERSIDADE ESTADUAL DE CAMPINAS	CNPJ: 46.068.425/0001-33

Registro de coleta imprevista de material biológico

De acordo com a Instrução Normativa nº 03/2014, a coleta imprevista de material biológico ou de substrato não contemplado na autorização ou na licença permanente deverá ser anotada na mesma, em campo específico, por ocasião da coleta, devendo esta coleta imprevista ser comunicada por meio do relatório de atividades. O transporte do material biológico ou do substrato deverá ser acompanhado da autorização ou da licença permanente com a devida anotação. O material biológico coletado de forma imprevista, deverá ser destinado à instituição científica e, depositado, preferencialmente, em coleção biológica científica registrada no Cadastro Nacional de Coleções Biológicas (CCBIO).

Táxon*	Qtde.	Tipo de amostra	Qtde.	Data

* Identificar o espécime no nível taxonômico possível.

Este documento (Autorização para atividades com finalidade científica) foi expedido com base na Instrução Normativa nº 03/2014. Através do código de autenticação abaixo, qualquer cidadão poderá verificar a autenticidade ou regularidade deste documento, por meio da página do Sisbio/ICMBio na Internet (www.icmbio.gov.br/sisbio).

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Appendix III: Declaração de bioética e biossegurança

UNICAMP
COORDENADORIA DE PÓS-GRADUAÇÃO
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Universidade Estadual de Campinas
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Fone (19) 3521-6378. email: cpgib@unicamp.br
IB

DECLARAÇÃO

Em observância ao **§5º do Artigo 1º da Informação CCPG-UNICAMP/001/15**, referente a Bioética e Biossegurança, declaro que o conteúdo de minha Dissertação de Mestrado, intitulada "" ***The resilient frugivorous fauna of a degraded forest fragmente and its potential role in the enrichment of vegetation",*** ", desenvolvida no Programa de Pós-Graduação em Ecologia do Instituto de Biologia da Unicamp, não versa sobre pesquisa envolvendo seres humanos, animais ou temas afetos a Biossegurança.

Assinatura: Eduardo D Bligacci
Nome do(a) aluno(a): Eduardo Delgado Britez Rigacci

Assinatura: _____
Nome do(a) orientador(a): Wesley Rodrigues Silva

Data: 26/08/2019

Appendix IV: Declaração de direitos autorais

Declaração

As cópias de artigos de minha autoria ou de minha co-autoria, já publicados ou submetidos para publicação em revistas científicas ou anais de congressos sujeitos a arbitragem, que constam da minha Dissertação/Tese de Mestrado/Doutorado, intitulada " **The resilient frugivorous fauna of a degraded forest fragmente and its potential role in the enrichment of vegetation**", , não infringem os dispositivos da Lei n.° 9.610/98, nem o direito autoral de qualquer editora.

Campinas, 26 de Agosto de 2019

Assinatura : _____
Nome do(a) autor(a): **Eduardo Delgado Britez Rigacci**
RG n.° 41567671-x

Assinatura : _____
Nome do(a) orientador(a): **Wesley Rodrigues Silva**
RG n.° 7.690.326-6